# Temperature as a System Constraint in Transportation Electrification: Vehicle Adoption, Infrastructure Performance, and Thermal Measurement

Transportation electrification is a central strategy for reducing greenhouse gas emissions and advancing the decarbonization of the mobility sector. However, the long-term success of this transition depends not only on technological innovation, charging infrastructure, and policy support, but also on whether electric transportation systems can perform reliably under real and increasingly variable environmental conditions. Among these conditions, temperature represents a critical yet underexamined constraint. It influences battery efficiency, charging behavior, usable vehicle range, infrastructure performance, and ultimately user confidence in electric mobility. This dissertation examines temperature as a multi-scalar constraint on transportation electrification and provides empirical and methodological advances for understanding, quantifying, and incorporating thermal effects into the planning and evaluation of electric mobility systems.

The dissertation is organized around four studies. The first investigates whether temperature is associated with electric vehicle adoption in the United States using ZIP code-level data and machine learning. Results show that temperature variation and temperature extremes are among the strongest predictors of battery electric vehicle (BEV) and plug-in hybrid electric vehicle adoption, alongside conventional factors such as income, education, and charging infrastructure. The second study moves from prediction to inference by estimating the effect of temperature on BEV penetration using ZIP code-level panel data and a spatial econometric framework. It finds a nonlinear relationship in which BEV penetration is higher in thermally stable areas but declines as annual temperature variability increases, while frequent cold exposure also significantly suppresses market share.

The third study extends the dissertation from vehicle adoption to infrastructure performance by examining how full-scale dynamic wireless power transfer (DWPT) roadways behave thermally under real environmental exposure. Using calibrated thermal infrared (TIR) and co-registered RGB imagery collected from uncrewed aerial system (UAS) platforms, it demonstrates how both endogenous and exogenous factors contribute to infrastructure heating, and how UAS-based thermography can serve as a powerful tool for detecting hot spots and pavement-condition features relevant to durability and maintenance. The fourth study addresses the methodological challenge underlying such applications by improving the accuracy of temperature measurement in outdoor environments using UAS. It develops a practical calibration framework for mitigating radiometric bias in UAV TIR imagery using temperature-controlled reference plates. The proposed approach substantially improves temperature accuracy across flight altitudes and provides a field-deployable solution for quantitative thermal sensing.

Taken together, the dissertation shows that temperature affects transportation electrification at multiple levels, from vehicle adoption and performance to infrastructure behavior and

measurement. It argues that transportation electrification should be understood not only as an energy and infrastructure transition, but also as a thermal resilience challenge.