What happens when we have deep penetration of EVs?

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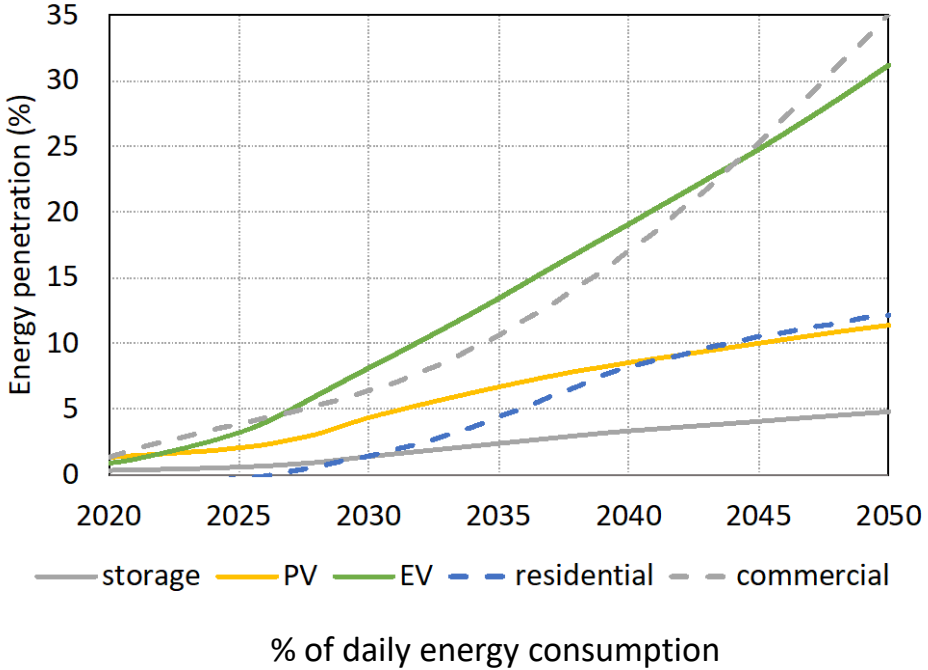
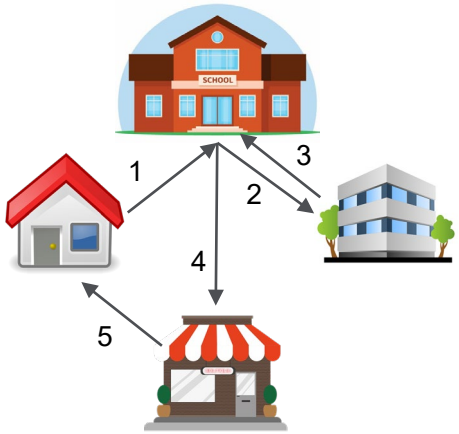
Some key challenges

- How to quantify the impact at the transmission and distribution level?
- What are the opportunities to mitigate this impact and what is their true potential at scale?
- How it impacts people?



Determinants of EV charging demand and flexibility

1. Behavior and Preferences



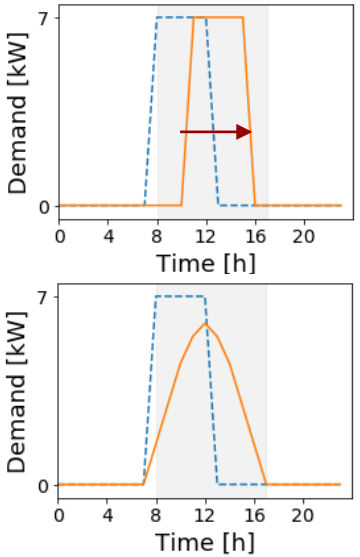
Where/when do they want/need to charge?

→ Change Prices or Range

2. Charging Infrastructure

→ Increase Access

3. Controlled Charging

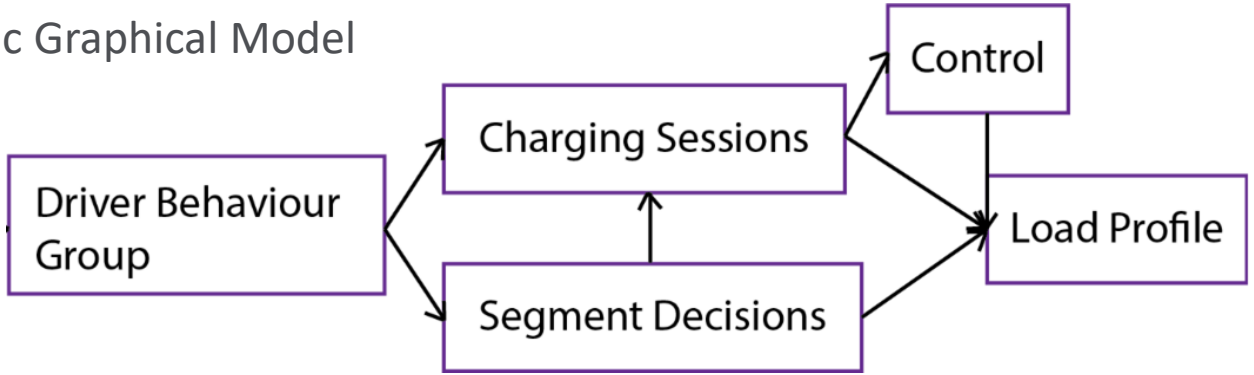


→ Change Signals

SPEEch: Scalable and Probabilistic Estimates of EV Charging

- Open-source: https://github.com/Stanford-Sustainable-Systems-Lab/speech
- Builds in “knobs” for scenario design based on driver behaviour data

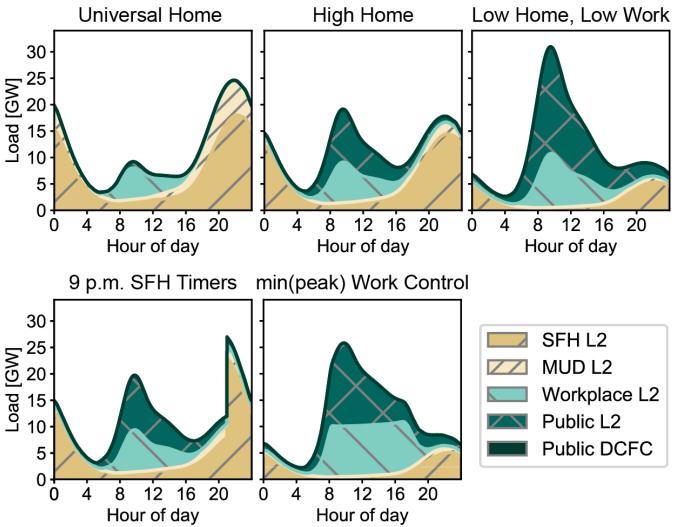
Probabilistic Graphical Model

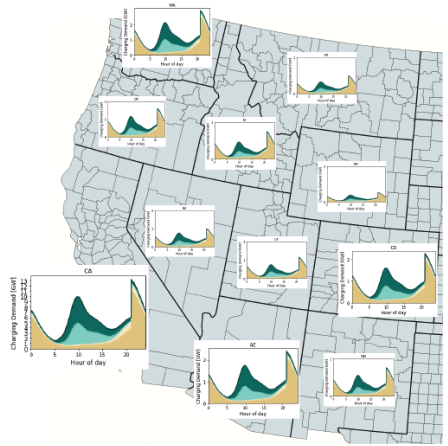


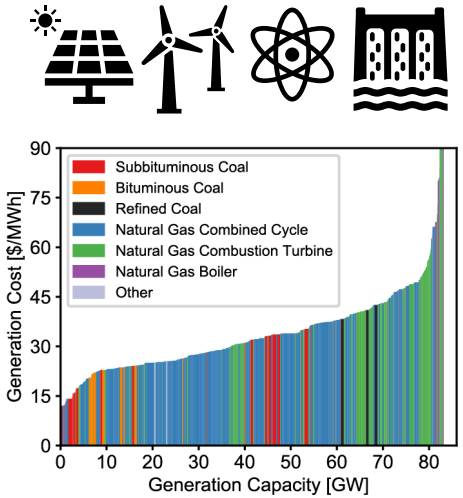
Powell, S., Cezar, G. V. & Rajagopal, R, Scalable probabilistic estimates of electric vehicle charging given observed driver behavior." Applied Energy, 309, 118382.

EV Demand Scenarios & 2035 Grid Dispatch

- Scenarios for interaction with infrastructure and controls
- Open-source model of WECC grid dispatch in 2035

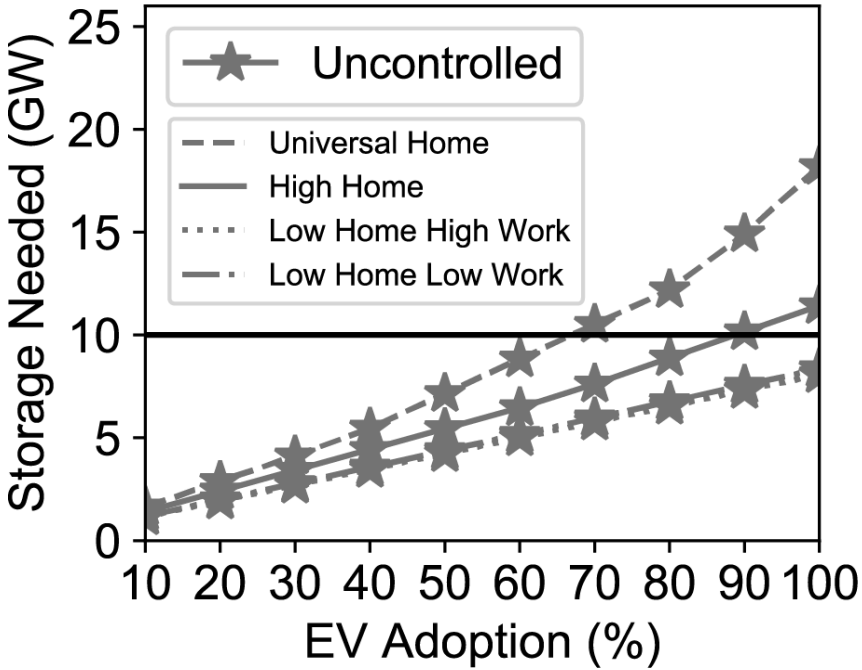


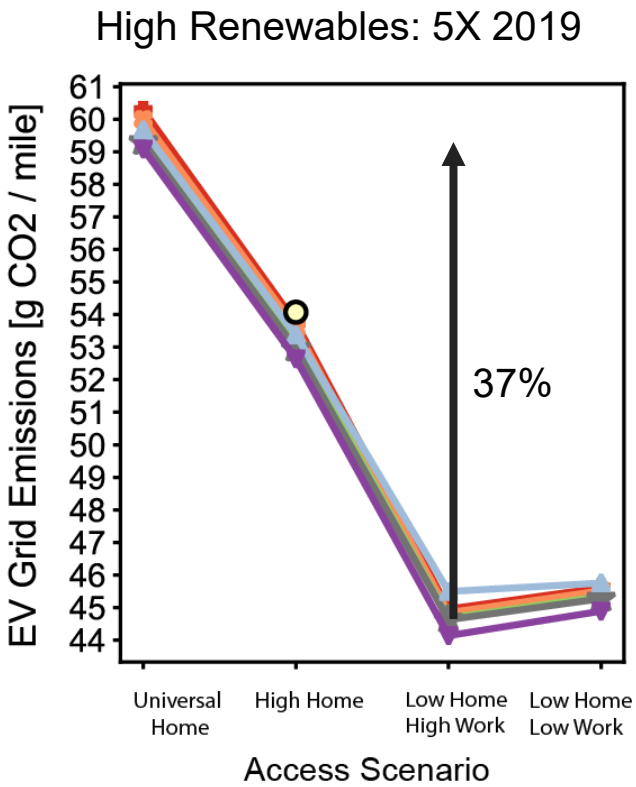




Powell, S., Cezar, G. V., Min, L., Azevedo, I. M., & Rajagopal, R. Charging infrastructure access and operation to reduce the grid impacts of deep electric vehicle adoption. *Nat Energy* **7**, 932-945 (2022). https://doi.org/10.1038/s41560-022-01105-7

Daytime charging is the most critical driver of impact





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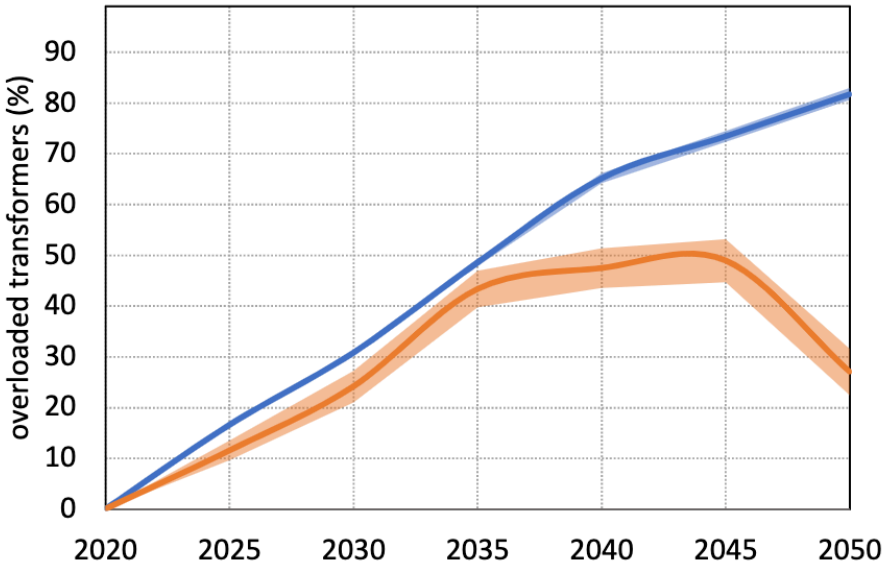
What is the distribution grid impact?

Current local DER control, which aims to minimized electricity cost X

Centralized DER control that jointly optimizes for reliability and cost



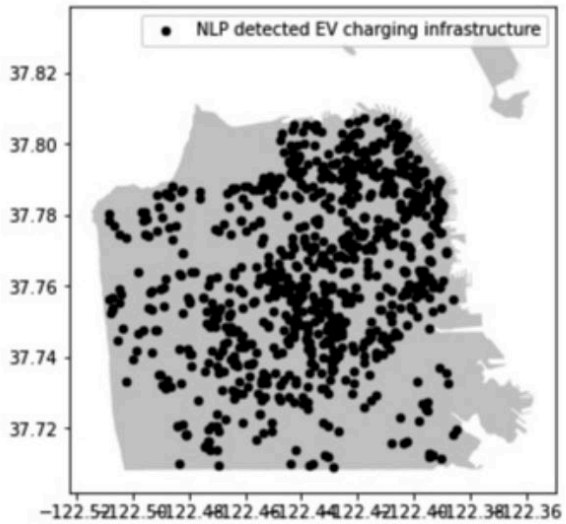
- Centralized controller reduces required infrastructure upgrades
- Peak load: from 150% to 80% as compared to local control

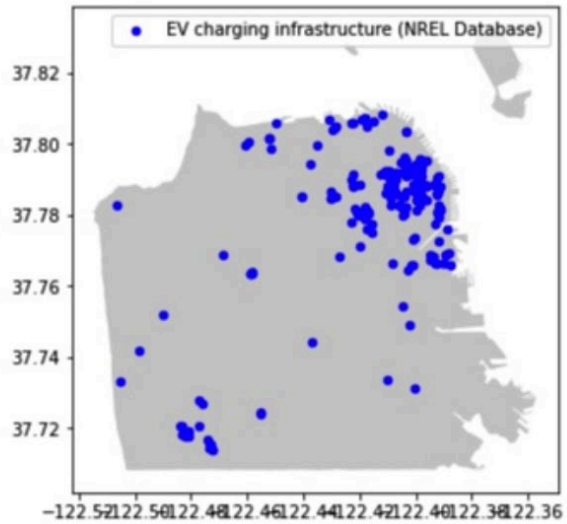
Navidi, T., El Gamal, A. & Rajagopal, R.. Coordinating Distributed Energy Resources for Reliability can Significantly Reduce Future Distribution Grid Upgrades and Peak Load, revise and resubmit (Joule), 2023

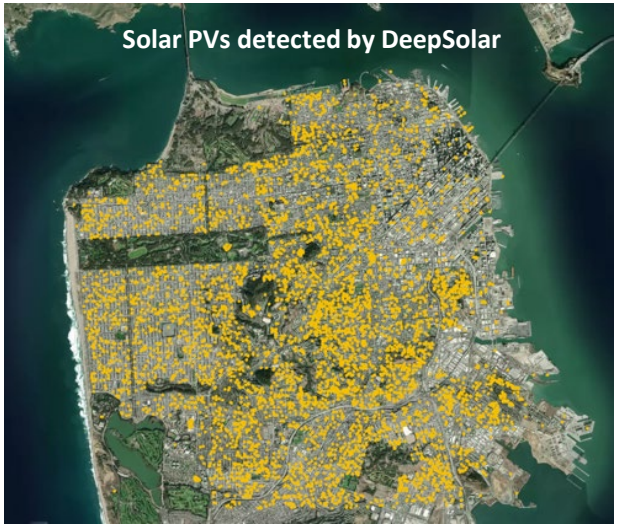
How it impacts people?

EV chargers detected by our NLP model

EV chargers documented in the NREL database





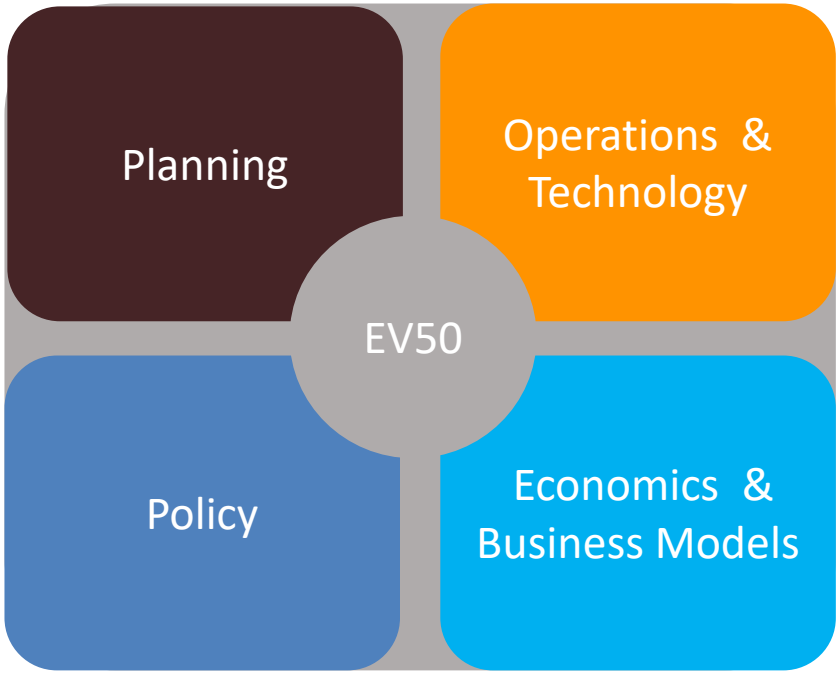


Geospatial distribution (San Francisco)

- Unequal access and unequal resilience
- Inequity is significantly smaller across commercial installations

Oladeji, O., Wang, Z., & Rajagopal, R. (2023). Where are the plugs? NLP-driven mapping of Electric Vehicle Charging Infrastructure from building permits. In submission.

How to prepare the grid and manage charging?



- Determine infrastructure demand and impact
- Capacity planning with EVs and PV
- Design stations for rapid deployment
- Co-manage transport service and charging in fleets
- Manage lifecycle of battery systems
- 24x7 Carbon Free vehicle electrification
- Efficiently price charging and network services
- Design contracts for EV flexibility
- Assess preparedness for utilities and cities

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