Electric Vehicles and Charging Infrastructure Systems: Adoption, Deployment, and Management Insights

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Grand Challenge: Decarbonize Transportation Systems

Climate change mitigation requires massive shifts to clean vehicle technologies and travelers' attitude change

Energy and air quality burdens disproportionally incurred by **disadvantaged communities**

Resilience of sustainable transport systems and infrastructure against extreme events

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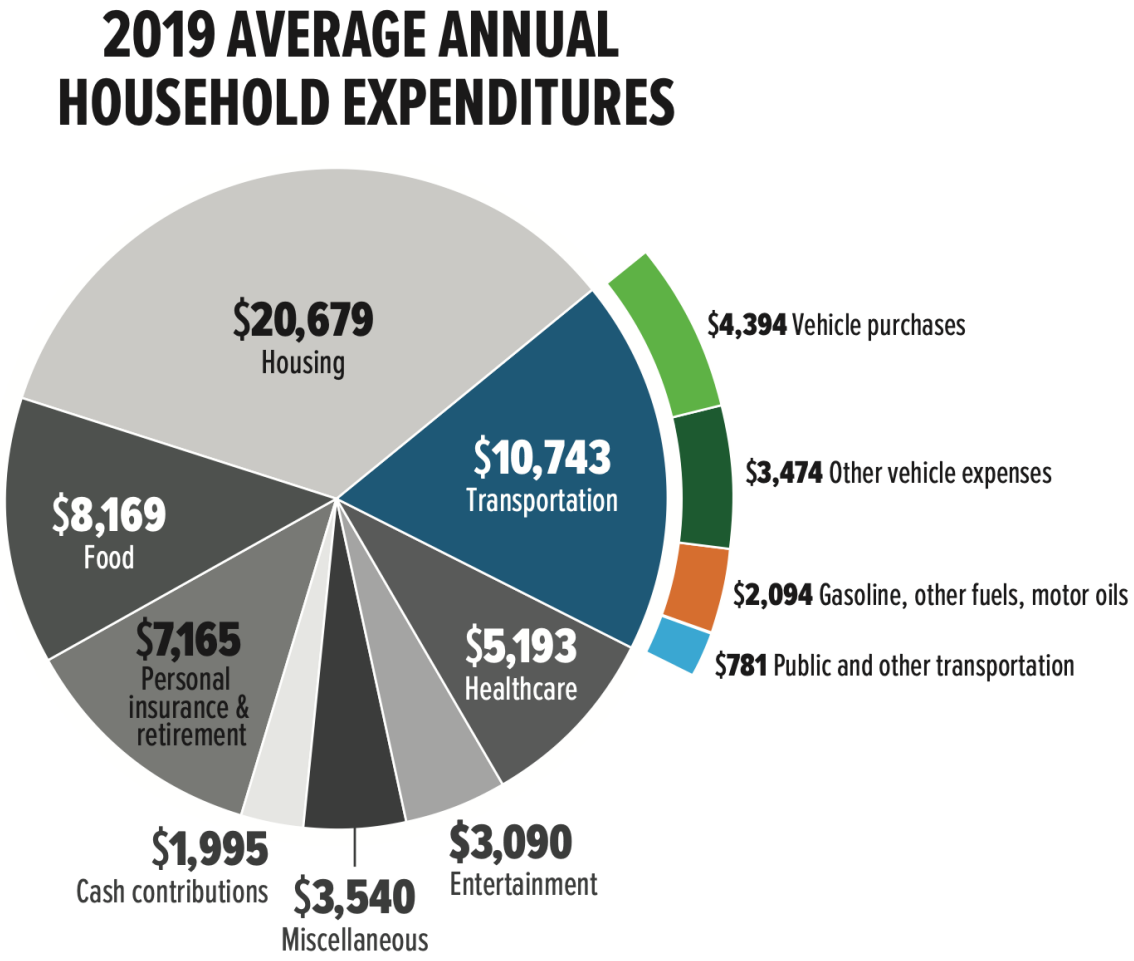
Transport **Energy Burden**



- **Significant transport costs for overburdened households**
  - Gasoline & diesel price volatility is an economic uncertainty for households and businesses

Data source: U.S. Bureau of Labor Statistics. Consumer Expenditure Surveys (2019)
Figure source: The U.S. National Blueprint for Transportation Decarbonization (2023)

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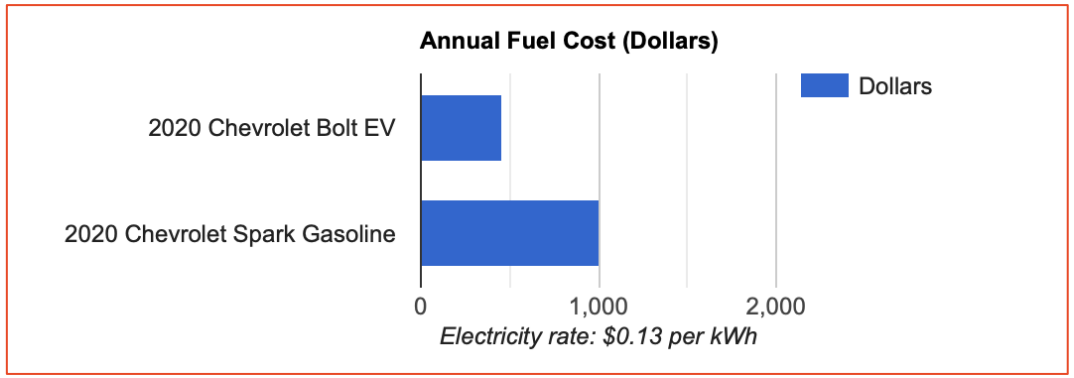
Light-Duty **Transport Electrification** Real Impacts

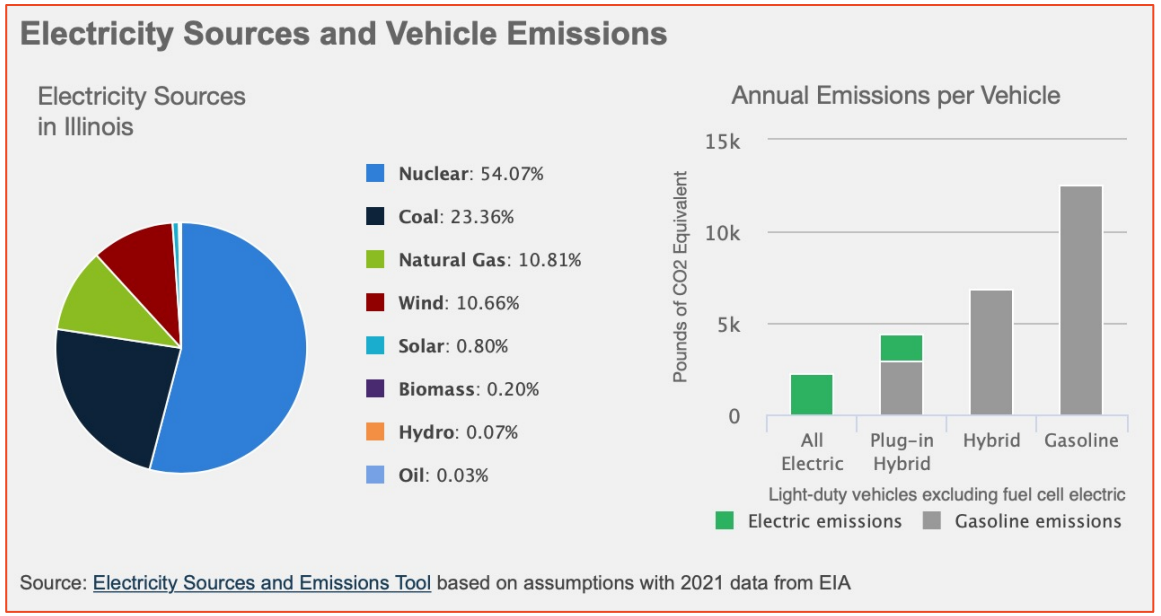


Travel Cost Savings

- EV $453 vs CV $1,000 per year

Emissions Reduction

- 82% annual CO2-eq decrease



Figures source: Alternative Fuels Data Center. 2021. https://afdc.energy.gov/states/il

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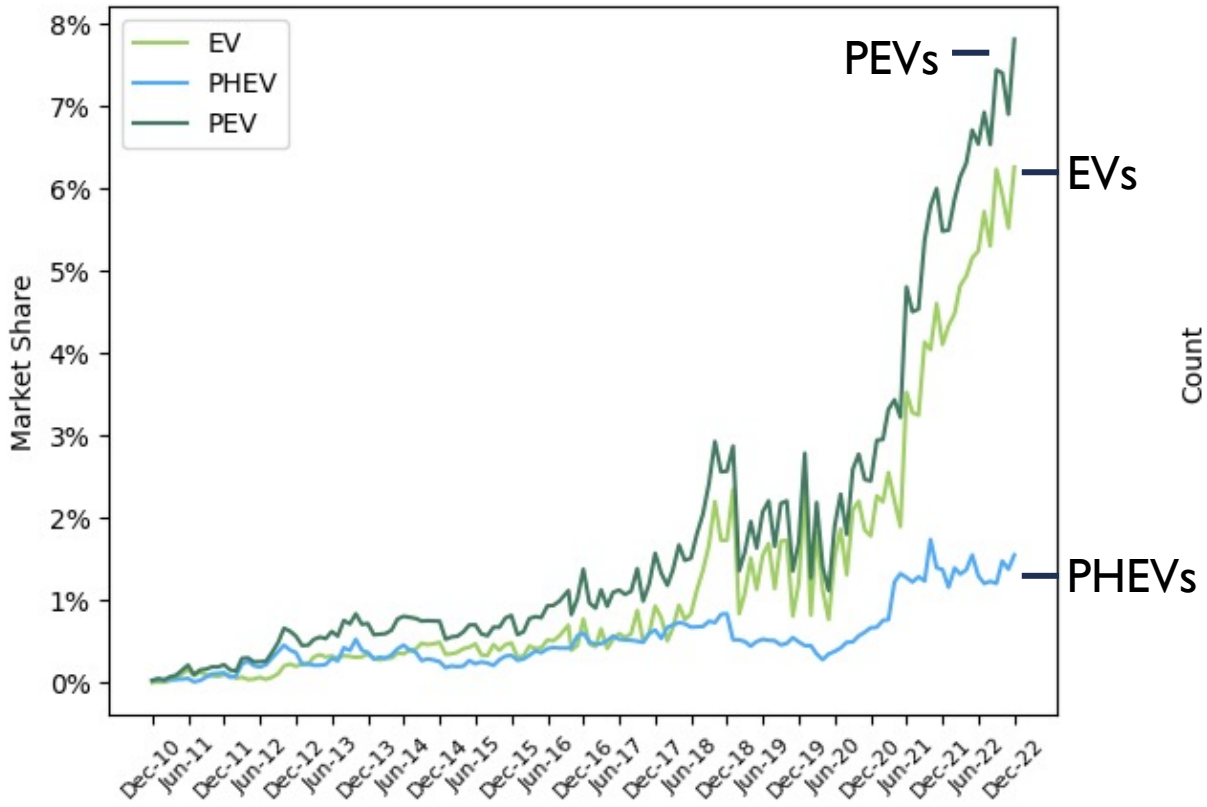
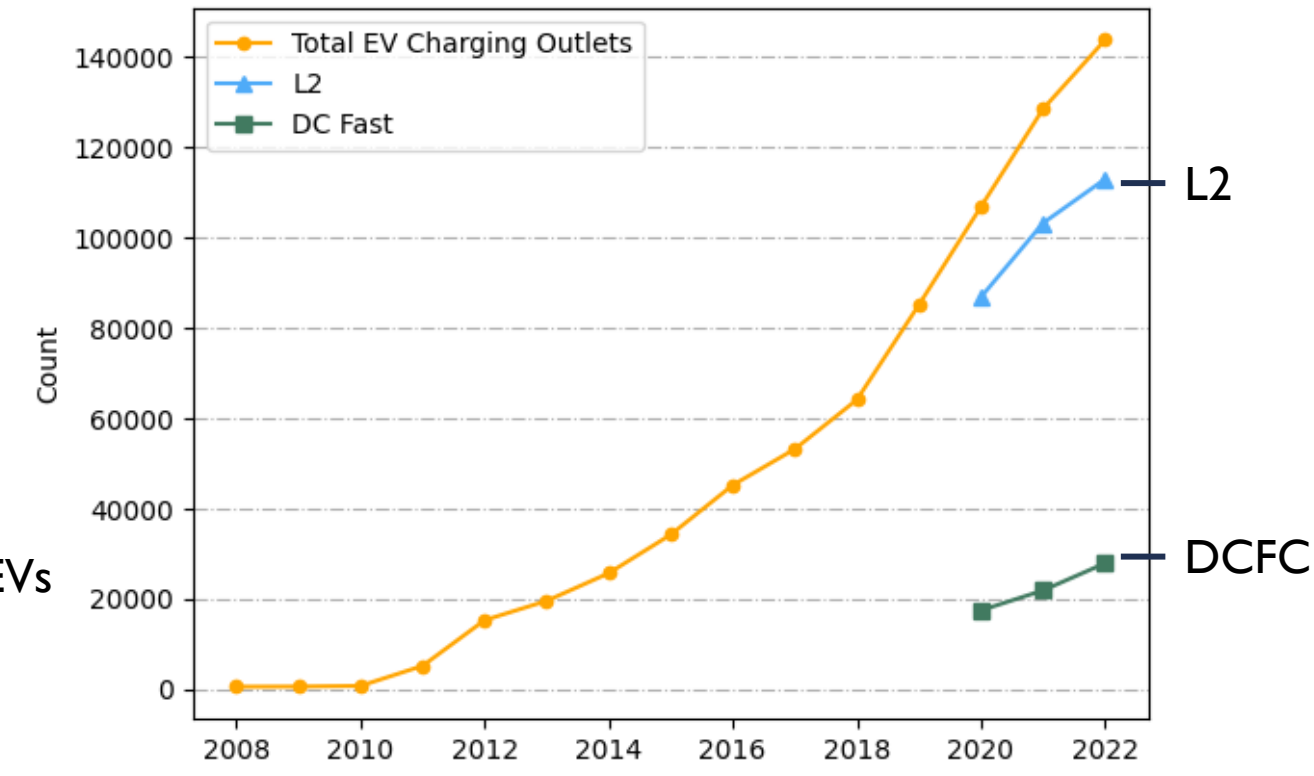
US Transition to Electric Vehicles

Light-duty plug-in vehicle monthly market share



Electric vehicle public charging ports



Data source: Alternative Fuels Data Center. 2023. https://afdc.energy.gov/stations/#/find/nearest

Data source: Department of Energy. 2023. https://www.energy.gov/eere/vehicles/articles/fotw-1275-january-30-2023-monthly-plug-electric-vehicle-sales-united-states

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Charging **Locations**

Where do plug-in electric vehicle drivers charge on weekdays?

Battery EV owners:

- 88 % charging at home
- 24 % charging at work
- 17 % public charging

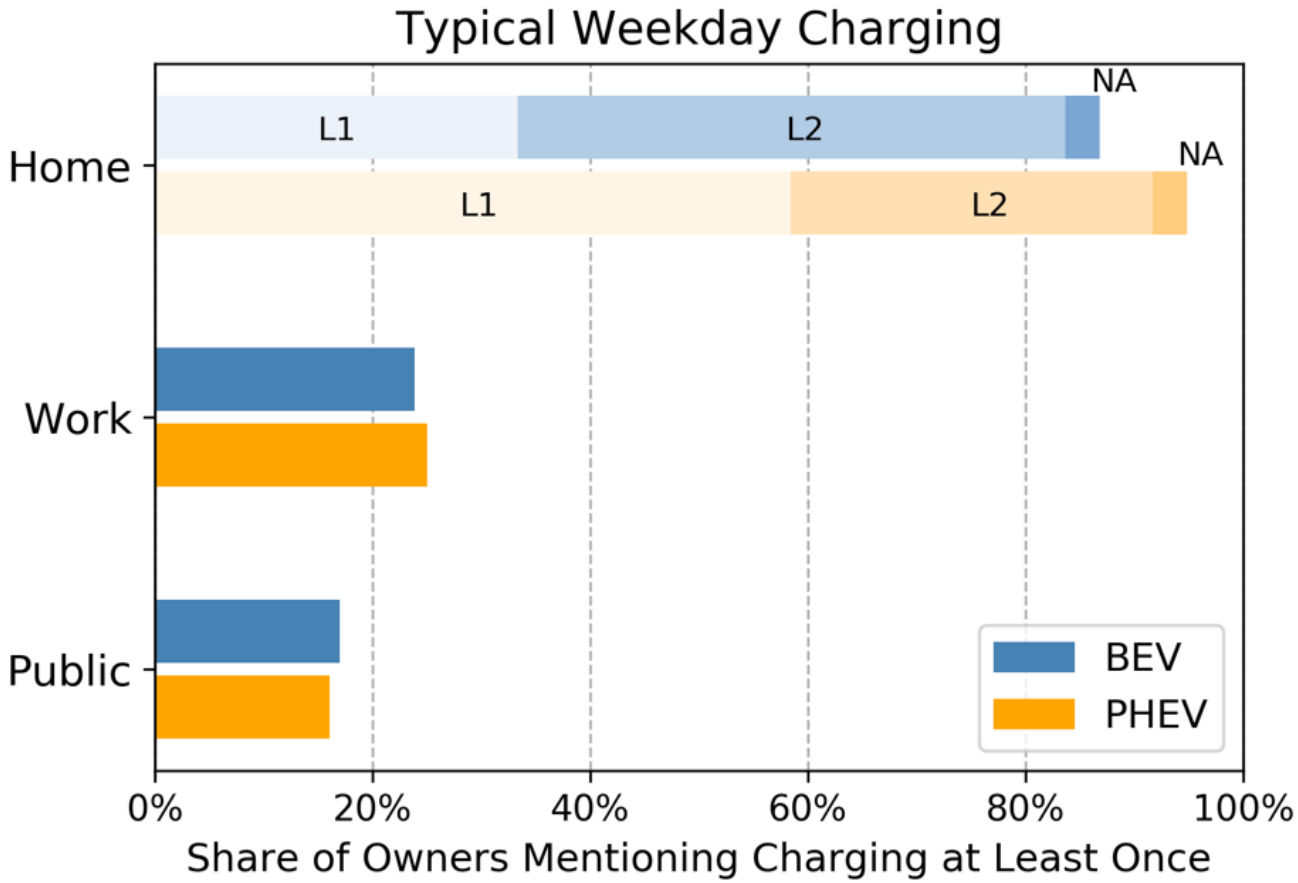

Figure from: Greene, Kontou, et al. 2020.
https://doi.org/10.1016/j.trd.2019.11.011

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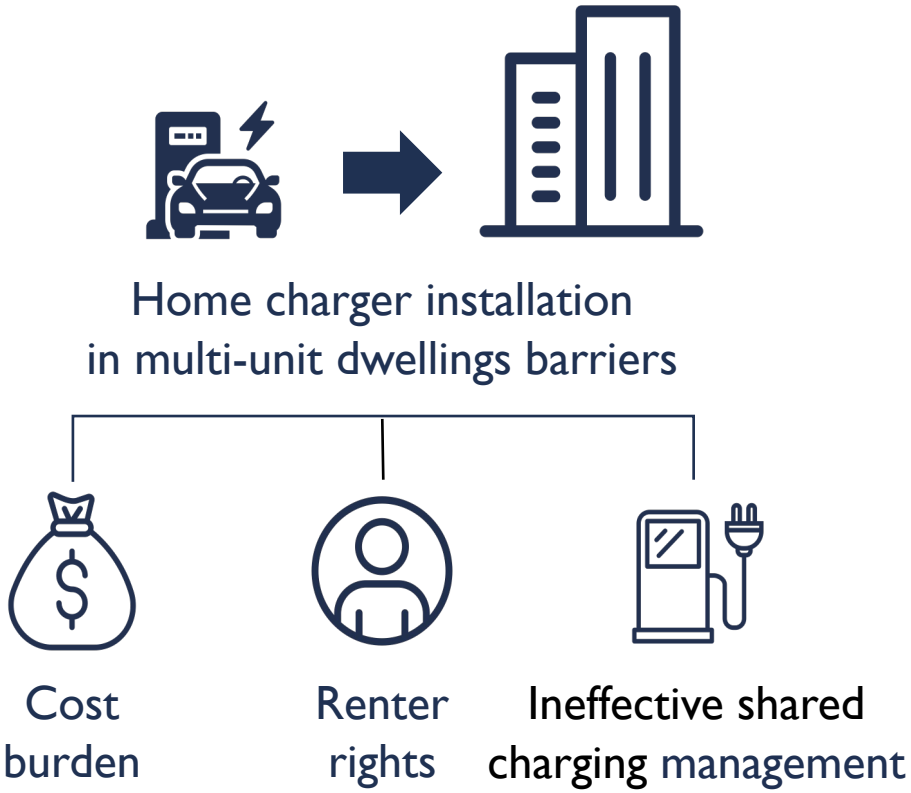
Ubiquitous **Residential** Charging ?

Multi-unit dwellers face barriers related to home parking and charging access



Limited access to reliable charging infrastructure could hinder electric vehicle adoption

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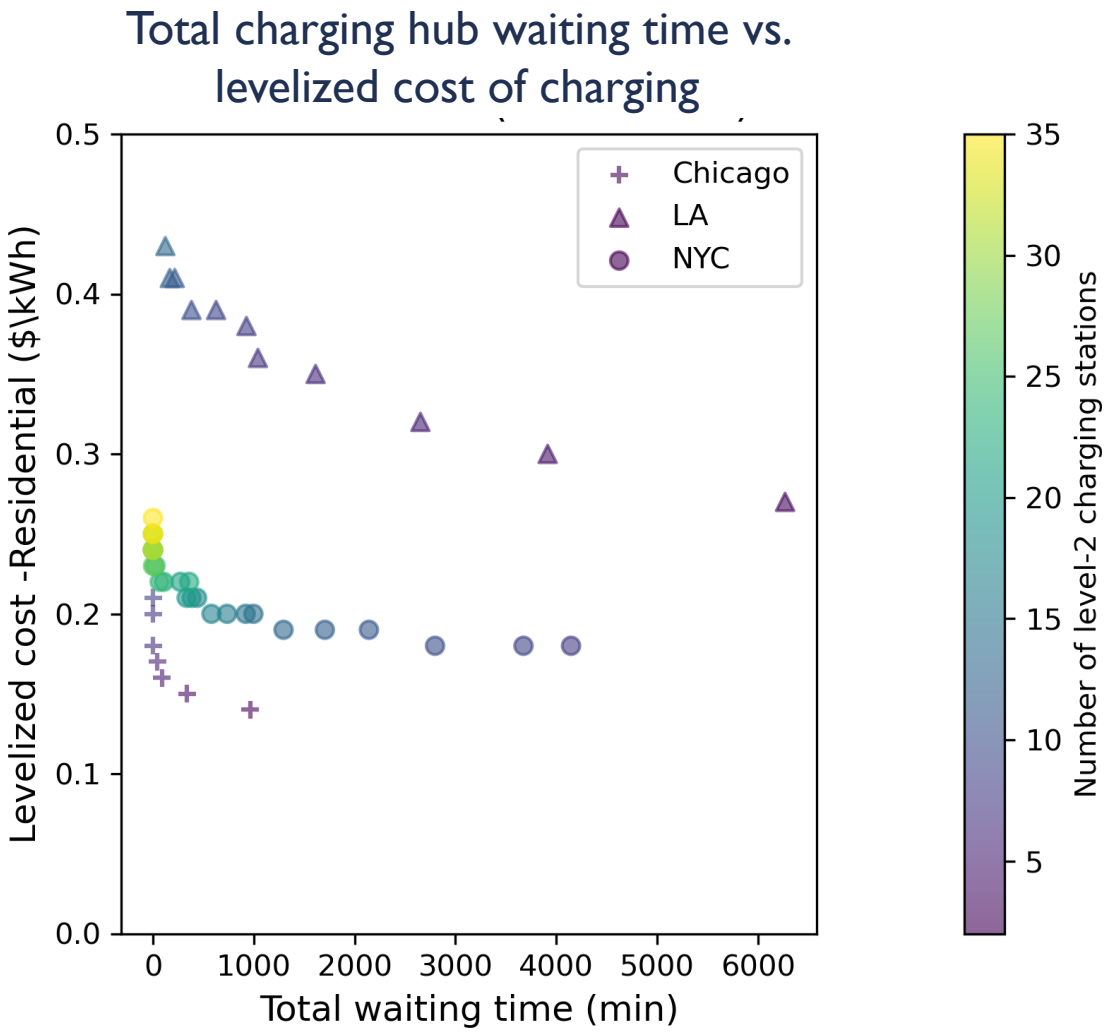
Shared Charging Management in Apartment Complexes

- Dynamic session-station allocation
- Day-ahead or stochastic residents charging demand
- Right-size infrastructure
- High station utilization
- Technoeconomic assessment of various business models
  - Residential ownership
  - Utility ownership
  - Private company ownership

Figure from: Zhang et al.
https://ssrn.com/abstract=4246024



Results for avg. number of vehicles per apartment complex based on 2019 American Housing Survey data

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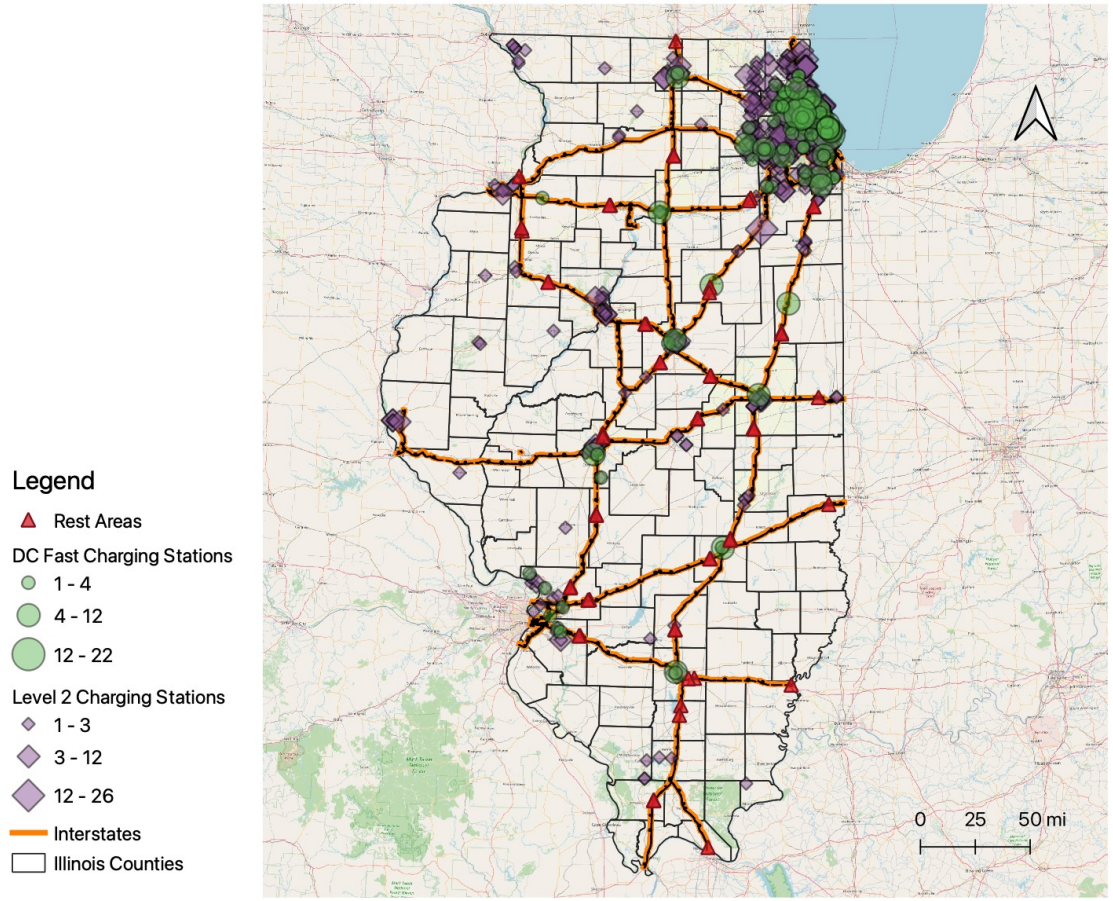
Public Charging Value

While most of the plug-in electric vehicle charging is expected to occur in residential locations, a network of **public chargers** provides tangible and intangible value by:

- Enabling long-distance travel
- Coping with range anxiety
- Supporting adopters that cannot reliably charge at residences & workplaces
- Building confidence in the future of EVs



Data source: Alternative Fuels Data Center. 2021. https://afdc.energy.gov/stations/#/find/nearest

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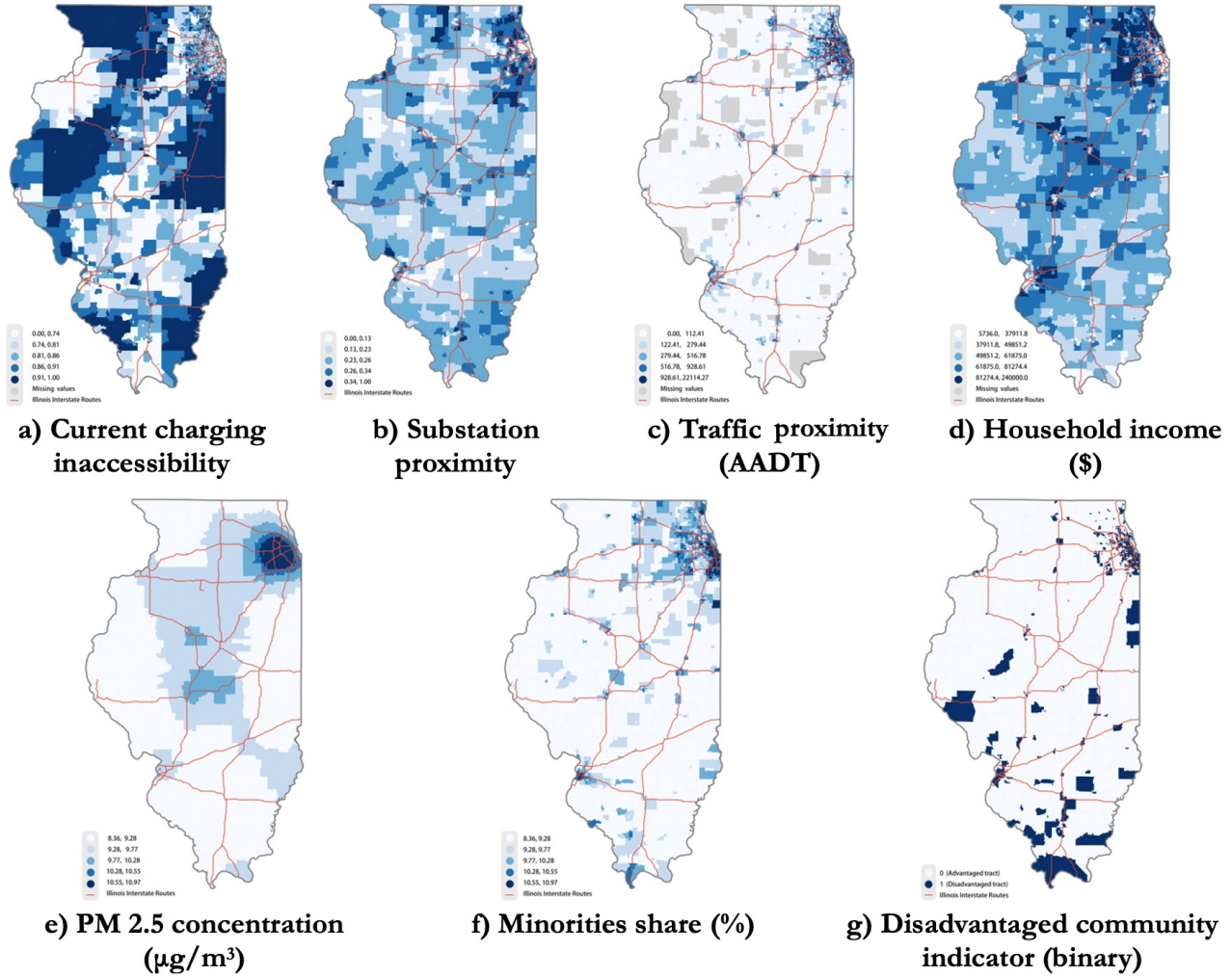
Planning for **Equitable** Charging Station **Deployment**

Charging facility location models responsive to **multiple stakeholders' feedback**

- Economic viability of network
- Electrical upgrades
- Environmental justice
- Disadvantaged and underserved population coverage and benefits



a) Current charging inaccessibility

b) Substation proximity

c) Traffic proximity (AADT)

d) Household income ($)

e) PM 2.5 concentration (μg/m³)

f) Minorities share (%)

g) Disadvantaged community indicator (binary)

Figure source: Kontou et al. 2023. https://doi.org/10.36501/0197-9191/22-023

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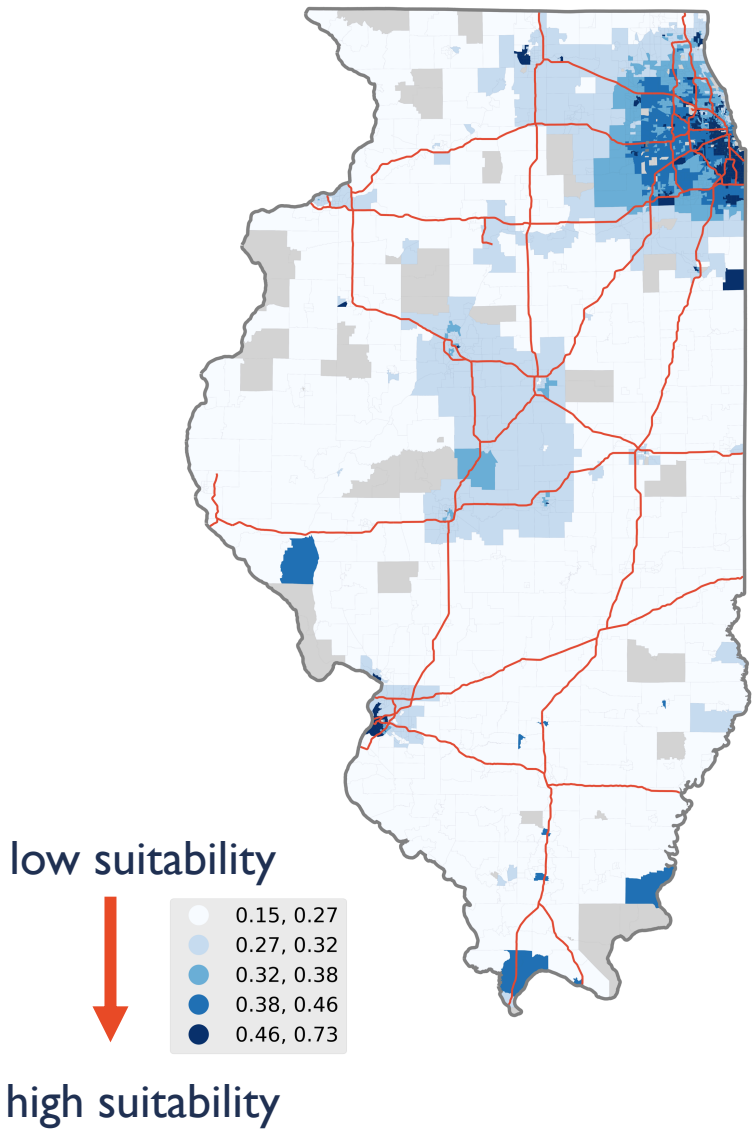

Figure source: Kontou et al. 2023.
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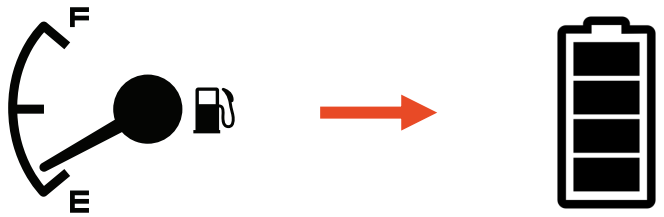
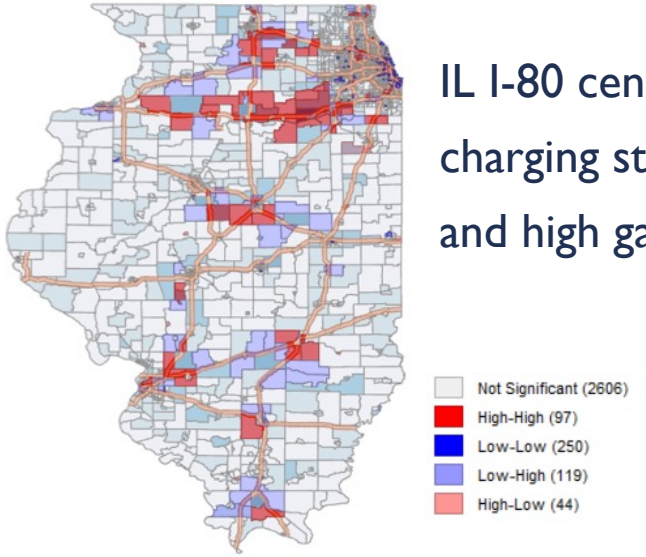
Mid-Transition Planning



Fossil system phasing out

- Gasoline stations and their supply chain's infrastructure as stranded assets
- What happens to these assets as the transportation sector goes electric?



IL I-80 census tracts have high charging station suitability and high gas stations sales

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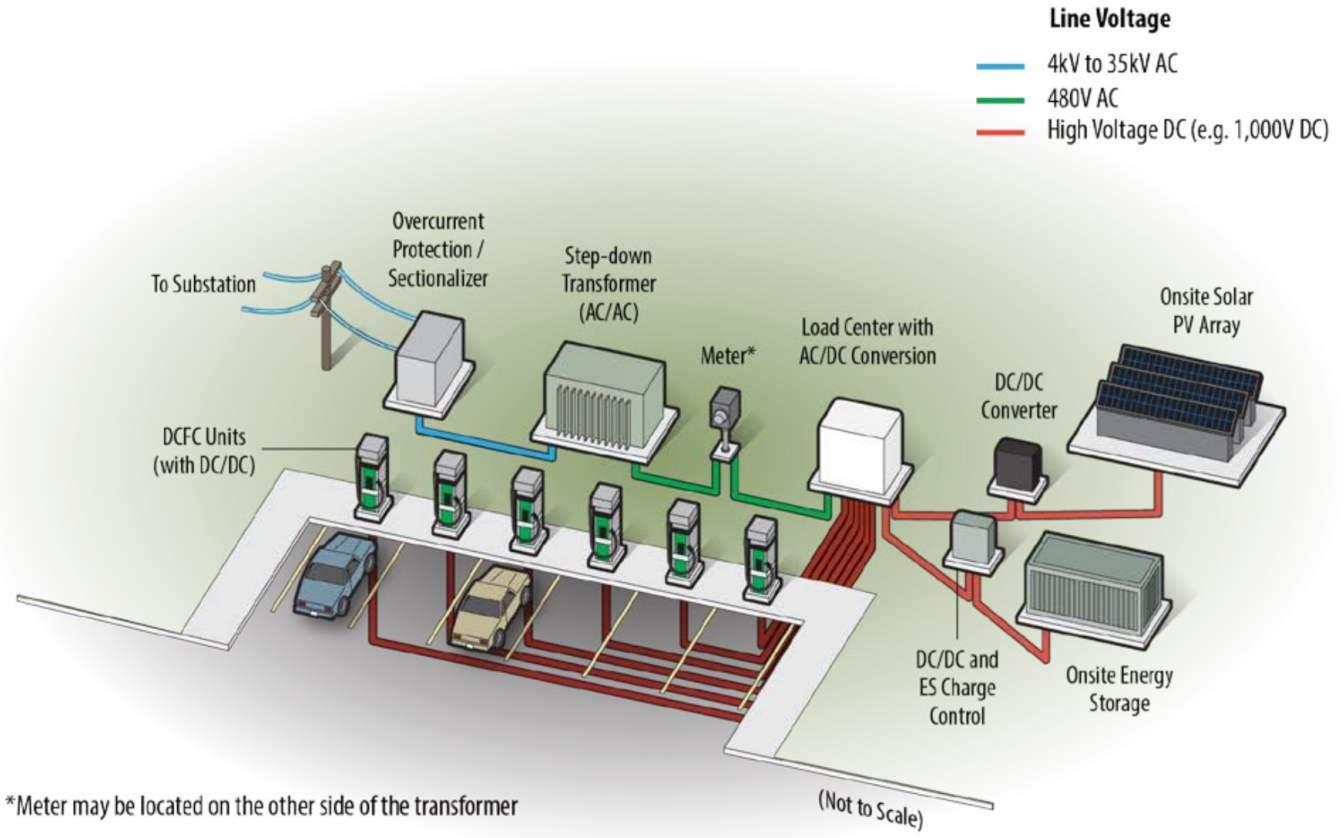
Electrified Charging Network by **Renewables**

Daily travel

- Charging electricity from renewable sources
- Electricity tariffs that incentivize clean energy use
- Charger providers lower costs from demand charges with renewables

Extreme events

- Enhance reliability of the system through microgrid connection



Picture from: Francfort et al. (2017). Link

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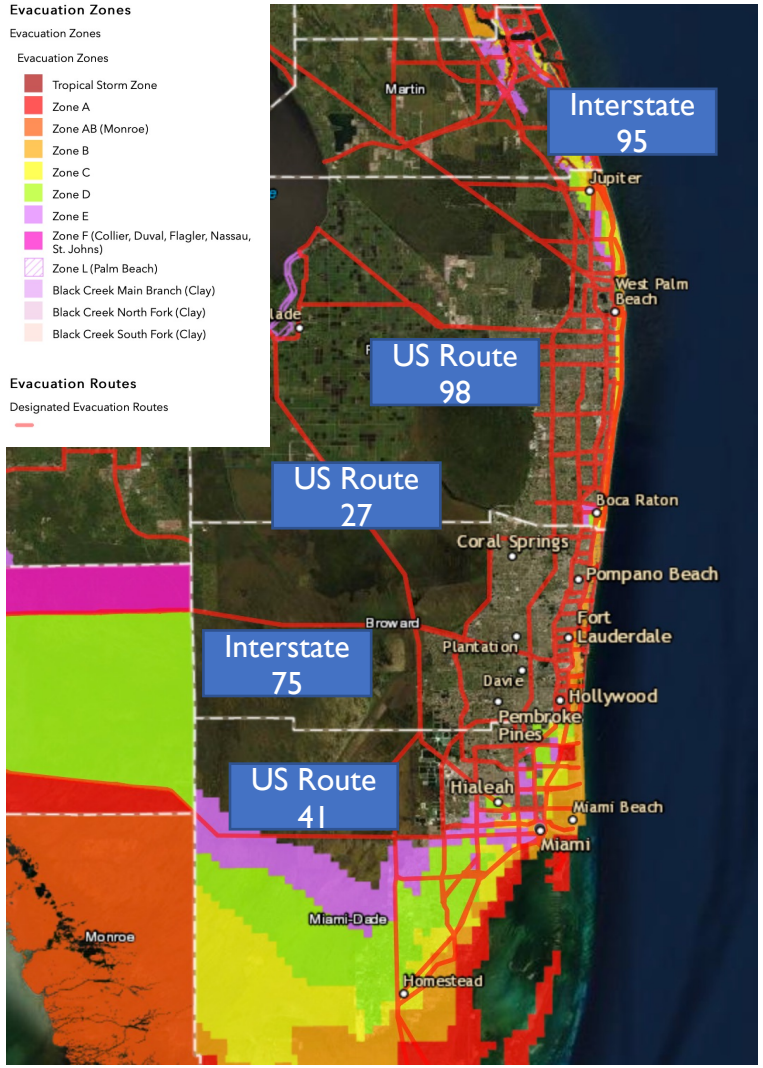
Evacuation with Electric Vehicles

South Florida Evacuation Network



Map source: https://www.floridadisaster.org/knowyourzone/

Florida Hurricane Disaster Declarations

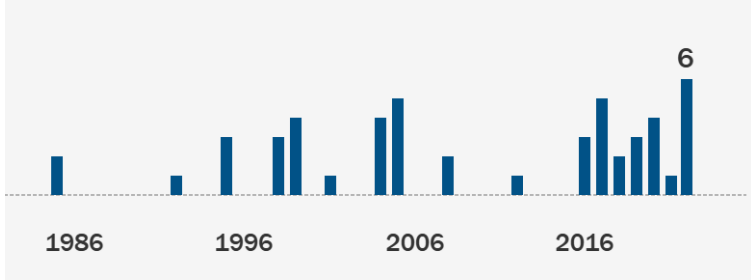


Figure source: FEMA. 2023.
https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties

Planning **Emergency/Portable** Charging Station Locations for Evacuations

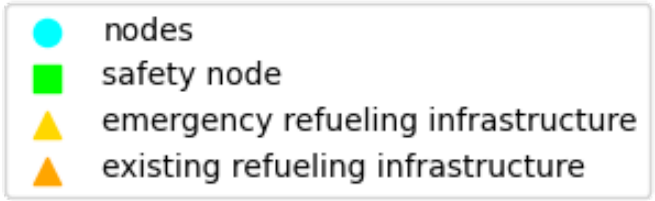
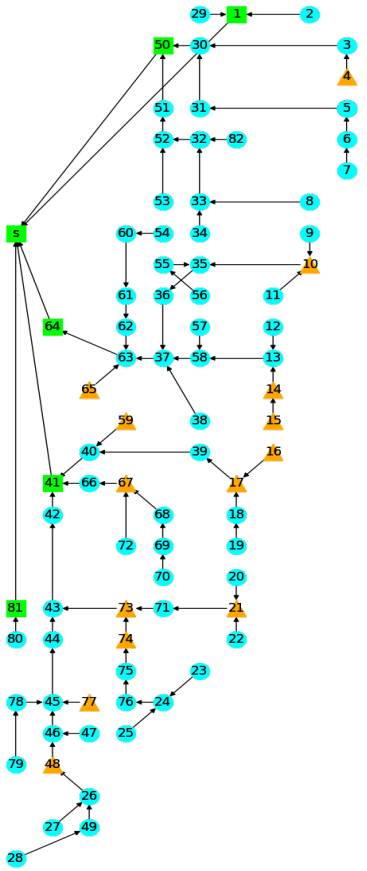


Figure source: Purba, Balisi, Kontou. In press.

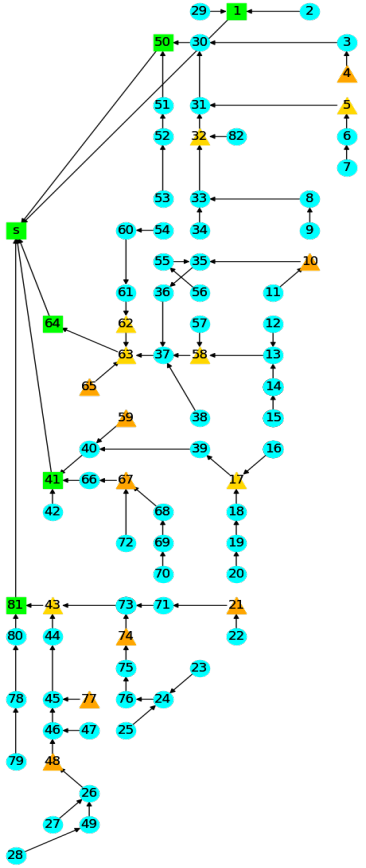
South Florida Evacuation Network

Gasoline Vehicles



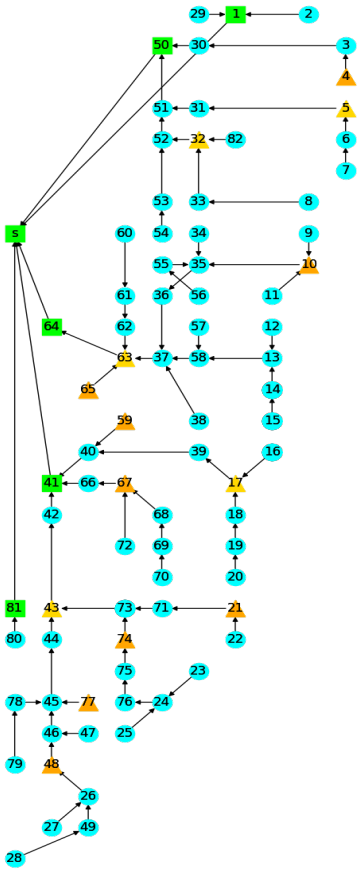
No additional stations

Medium Range Electric Vehicles



7 portable stations

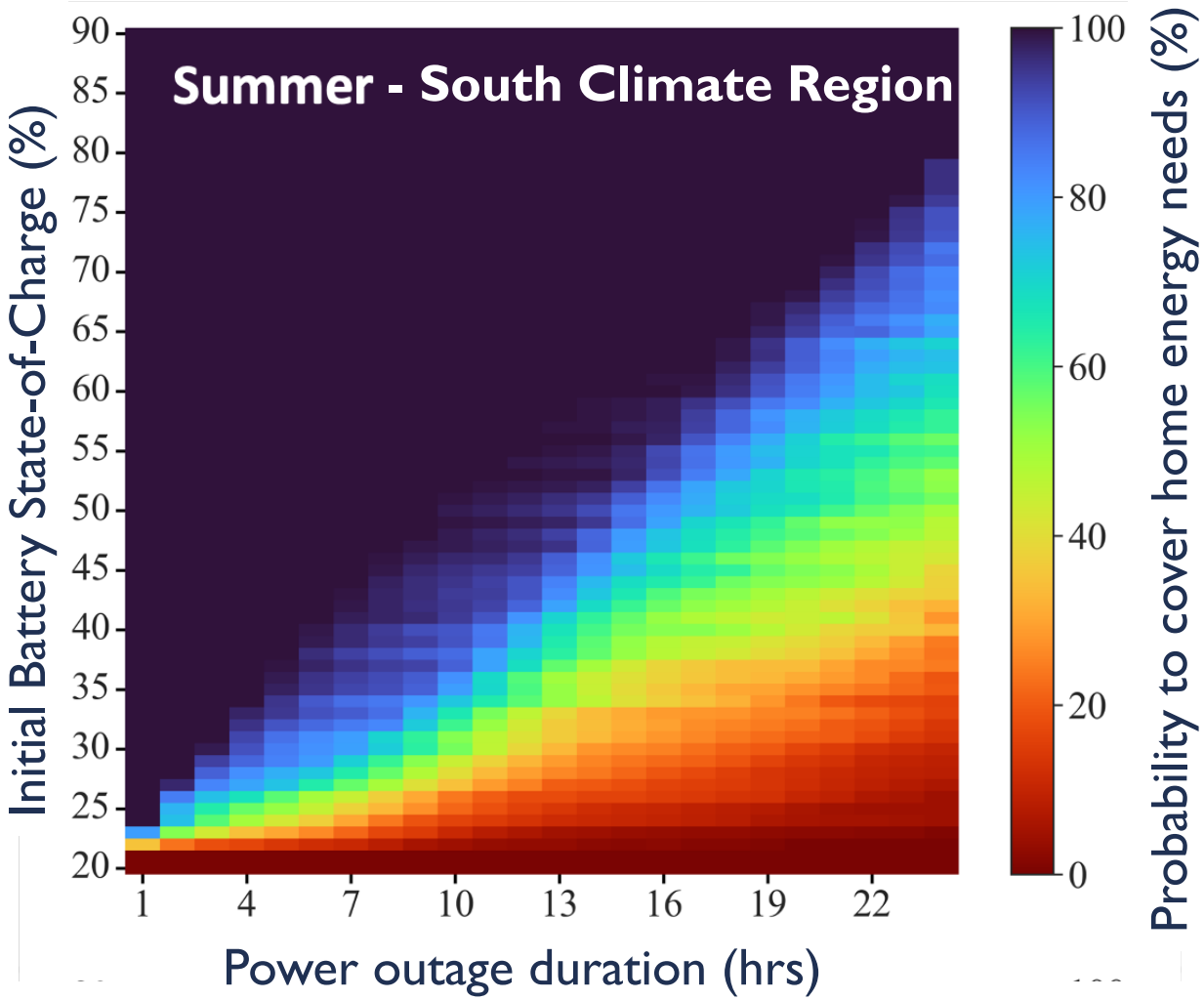
Long Range Electric Vehicles



5 portable stations

Electric Vehicle as a Resource During a **Power Outage**

Battery electric vehicle powers residential energy needs during outages through **vehicle-to-home technology**



Graph source: Liu, Vlachokostas, Kontou. In preparation.

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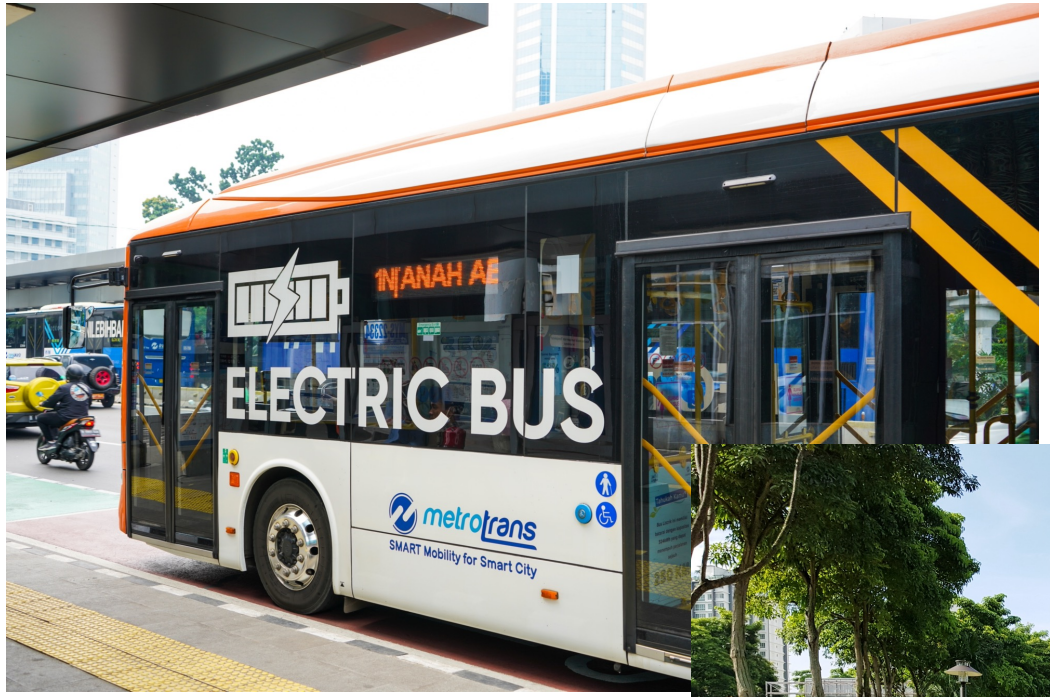
Sustainable, Resilient, Equitable Transport Systems



Thank you!

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