# Travel Behavior of EVs

## ECI 189G: Lecture 9

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# Why do we care how EVs drive?

- …to determine whether electric vehicles can meet travel demands of modern drivers
- …to determine how much and where infrastructure is needed to support the new technology
- …to determine the proper level of policy support—especially to align decarbonization efforts with costs associated with climate mitigation

# National Household Transportation Survey (NHTS)

- The NHTS is conducted by the Federal Highway Administration of the Department of Transportation
- The most comprehensive source of national data that measures trends in personal and household travel (does not include commercial travel)
- Collects data across many features: households, persons, person trips, person miles, vehicles, vehicle trips, vehicle miles, workers, and drivers
- Conducted roughly every decade, the current version was published in 2017 (previously 2009)

# NHTS Sampling

- In order to ensure accurate representation across the country, the NHTS must carefully design its sampling procedure:
  - Stratified sampling with add-on areas
  - Categorizes strata into four groups that depends on population density
  - Minimum allocation of 250 households per state
  - Etc…
- A 100+ document just on study design!
- Statistics are weighted to represent travel patterns correctly

Table 1-1 Study areas and target sample sizes

| Study Area | Sample Size[1] |
|---|---|
| National | 26,000 |
| Arizona DOT | 2,444 |
| California DOT | 24,000 |
| Des Moines Area MPO | 1,200 |
| Georgia DOT | 8,000 |
| Indian Nations Council of Governments | 1,000 |
| Iowa Northland Regional Council of Governments | 1,200 |
| Maryland DOT | 1,000 |
| New York State DOT | 15,851 |
| North Carolina DOT | 8,000 |
| South Carolina DOT | 6,500 |
| Wisconsin DOT | 11,000 |
| Texas DOT | 20,000 |
| North Central Texas Council of Governments | 2,917 |
| TOTAL | 129,112 |

[1]These are households for which all of the household members ages 5 and older complete the retrieval survey.

# Annual VMT from NHTS

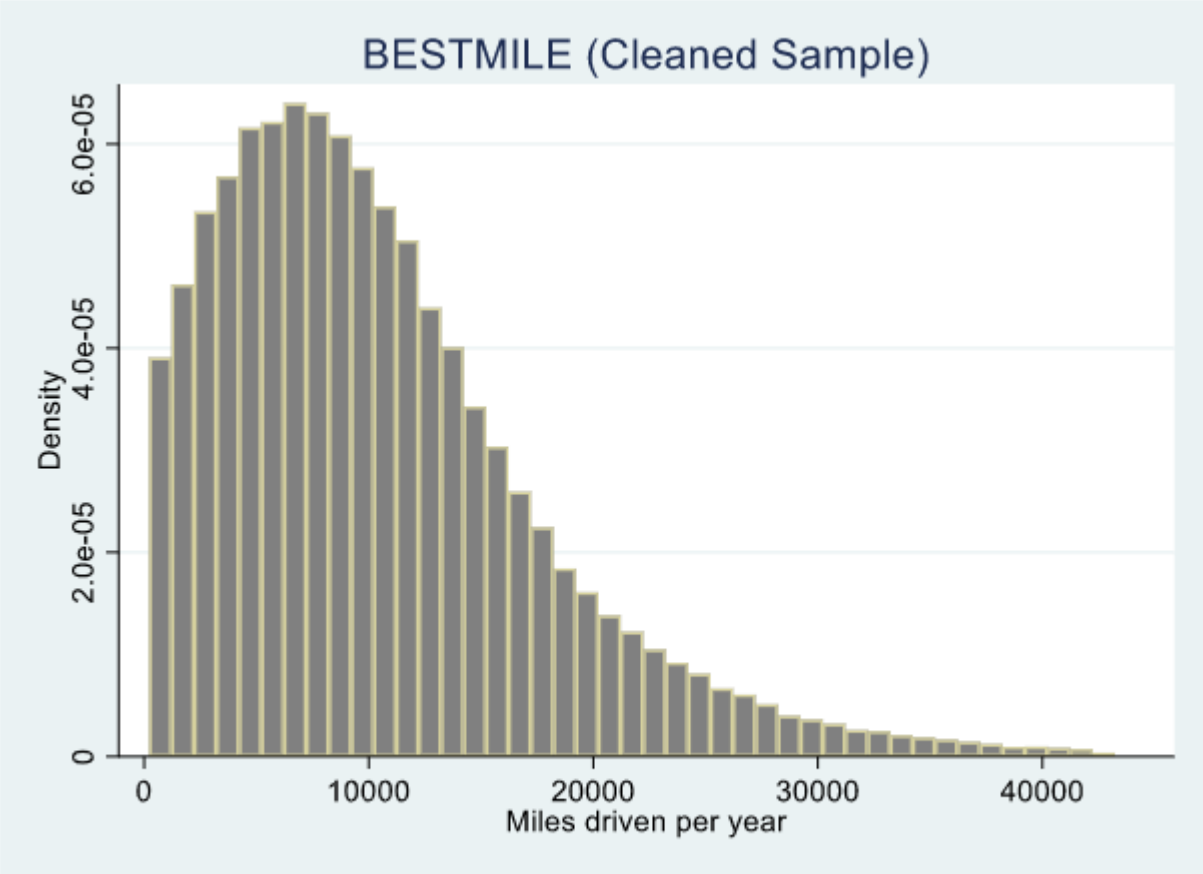



Fig. 5. Distribution of the best estimate of annual miles computed by NHTS.

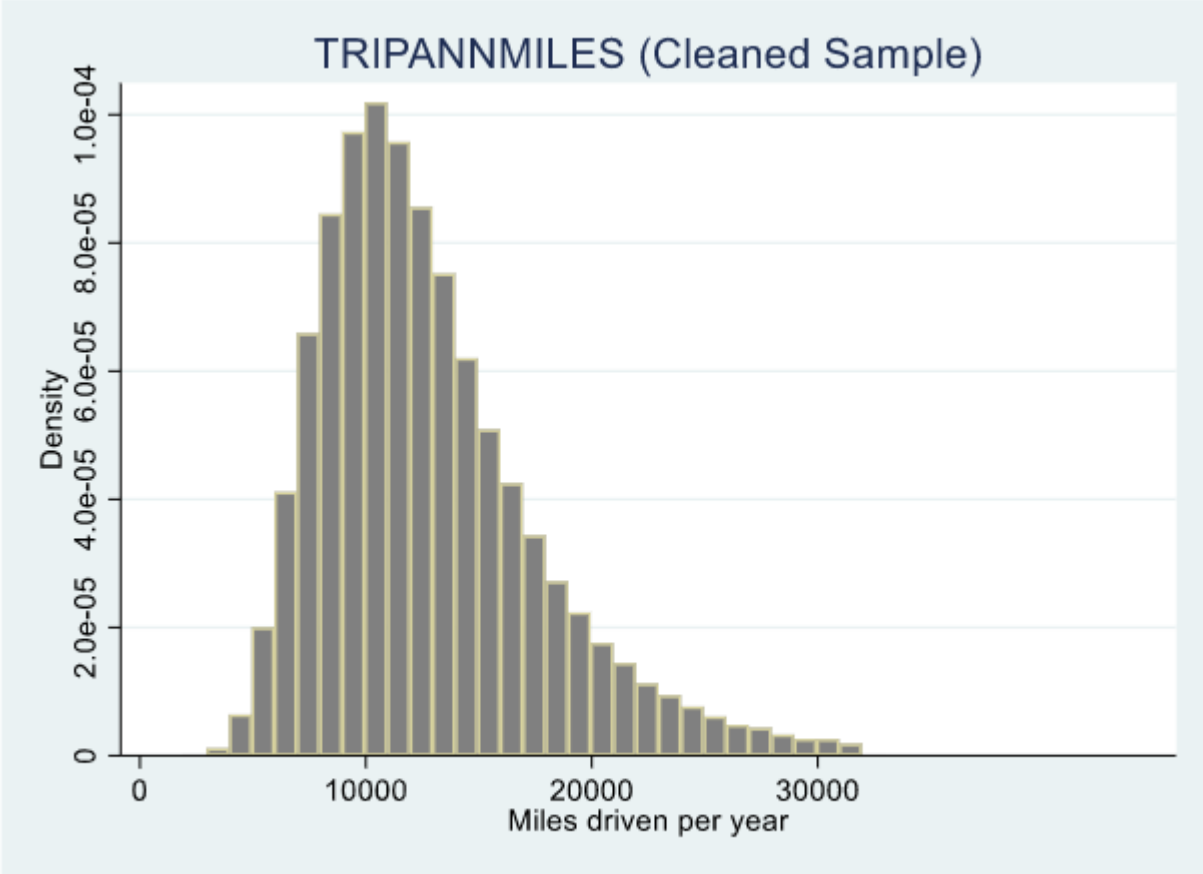



Fig. 8. Distribution of the annual miles estimated using the trip diary data.

# Vehicle age and VMT

- On average, newer vehicles are driven substantially more than older vehicles
- After 10 years, vehicles drop ~20% of their average annual VMT compared to when they were new

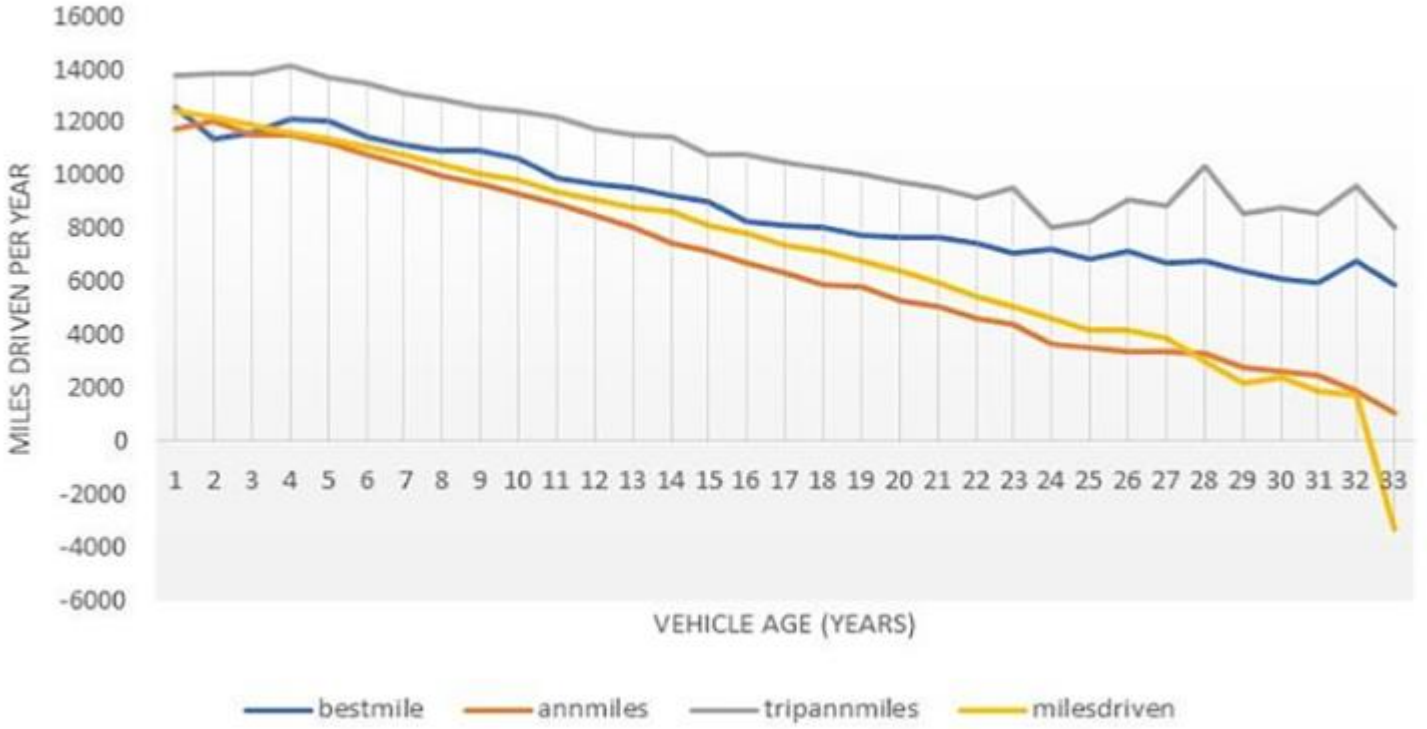



**Fig. 10.** Variation of the average VMT of four measures with respect to the vehicle age.

# California Household Transportation Survey

- The CHTS is similar to the NHTS, but specifically surveys California residents
- Surveys >42,500 households (109,113 participants)
- Data collection methods include telephone interviews, online/mail surveys, wearable (7,574) and in-vehicle (2,910) GPS devices, and OBD sensor data
- Also includes features such as vehicle-acquisition decisions, parking choices, work schedules, use of tolling, and walking/biking trips
- Most recent survey was 2010-2012, but there is a 2017 supplement to NHTS for California (add-on dataset)

# CHTS Sampling

**Figure 3.2: CHTS Household Counts by County**

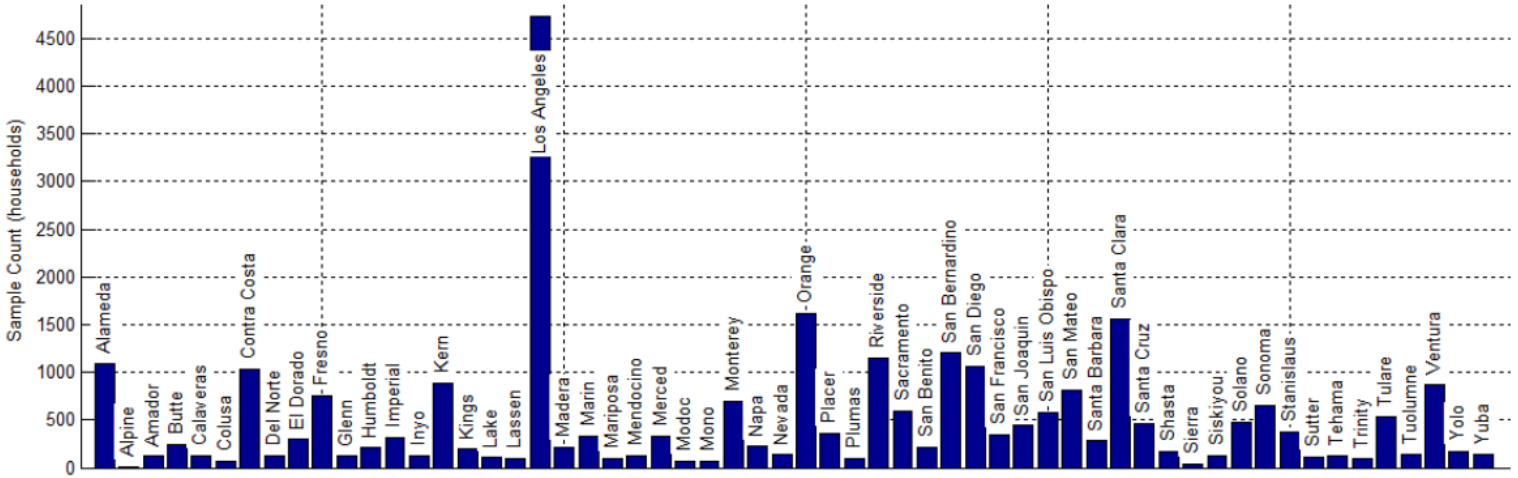
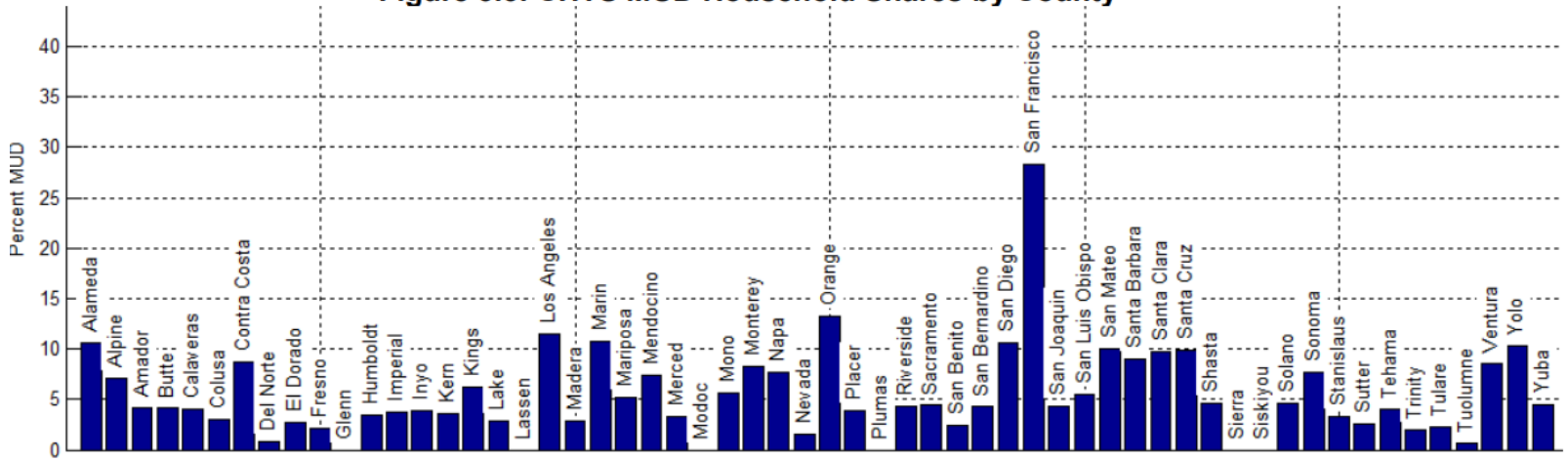



**Figure 3.3: CHTS MUD Household Shares by County**



# CHTS Daily Travel Behavior

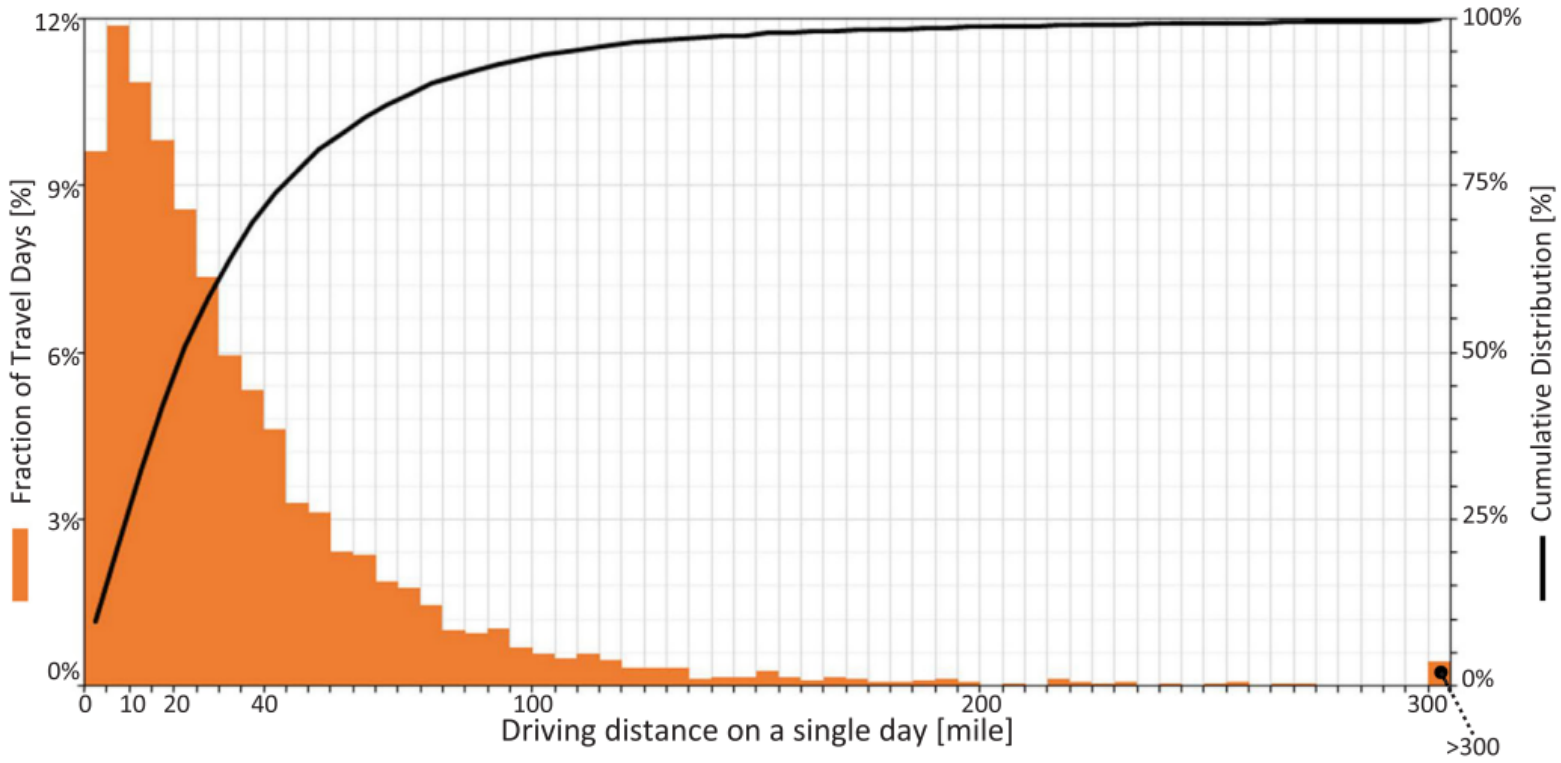
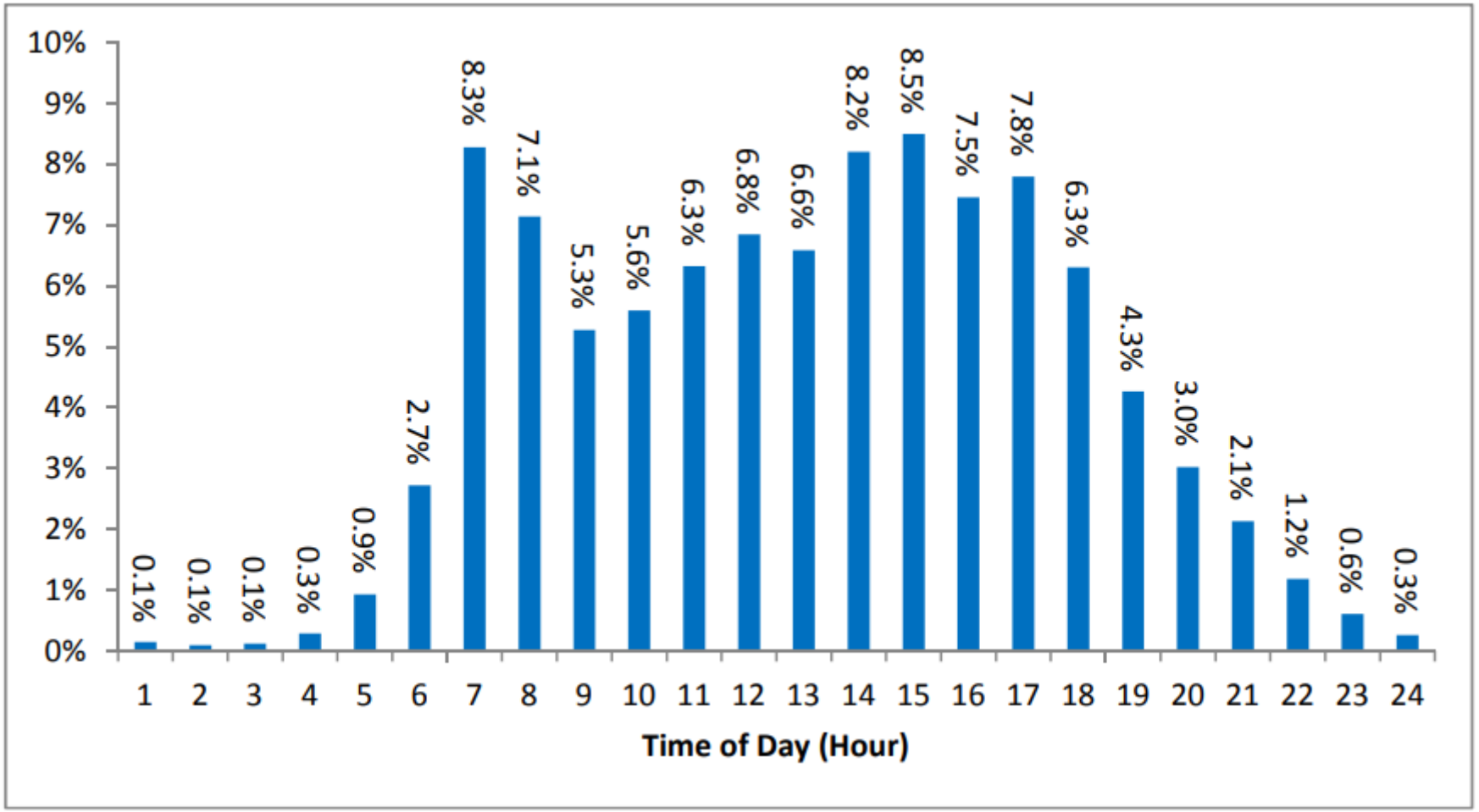



**Fig. 5.** Vehicle miles travelled (in CHTS data set) as function of miles driven on a single day.

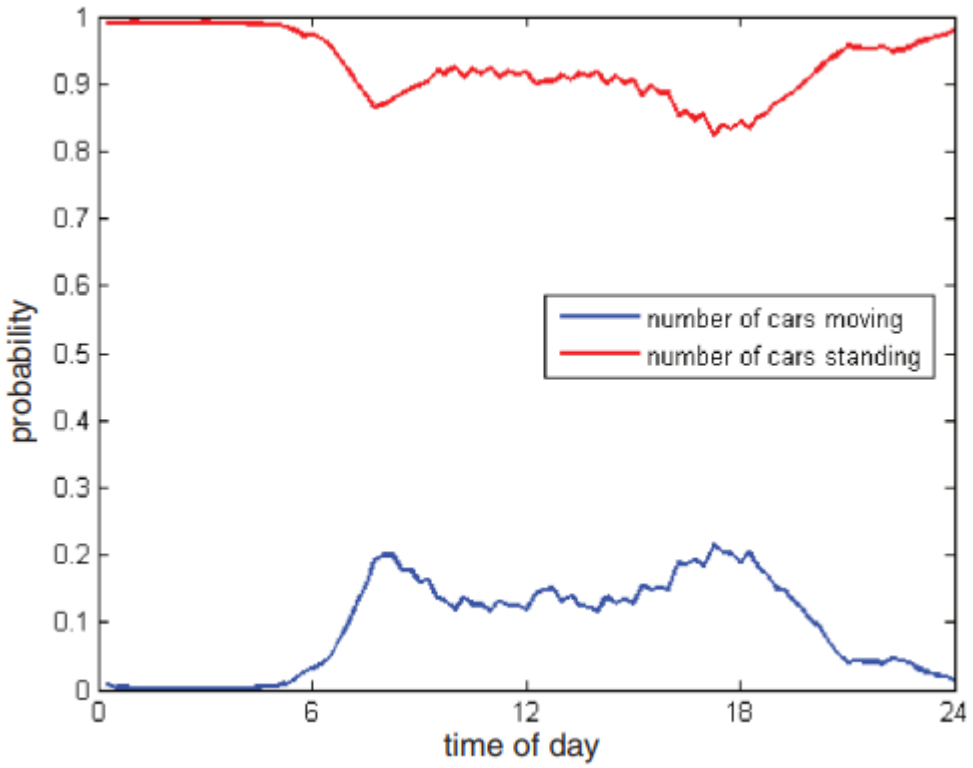
- Daily distances are relatively low – how do these relate to EV ranges?

# Hourly trip distribution by departure hours in CA



# How are charging patterns informed by travel behavior?

- The vast majority of time, vehicles are parked and standing still—not driving around
- Parked vehicles = potential opportunity for charging
- Understanding travel behavior can also help to place chargers in the right locations (where cars are parked)



# Travel behavior in EV research

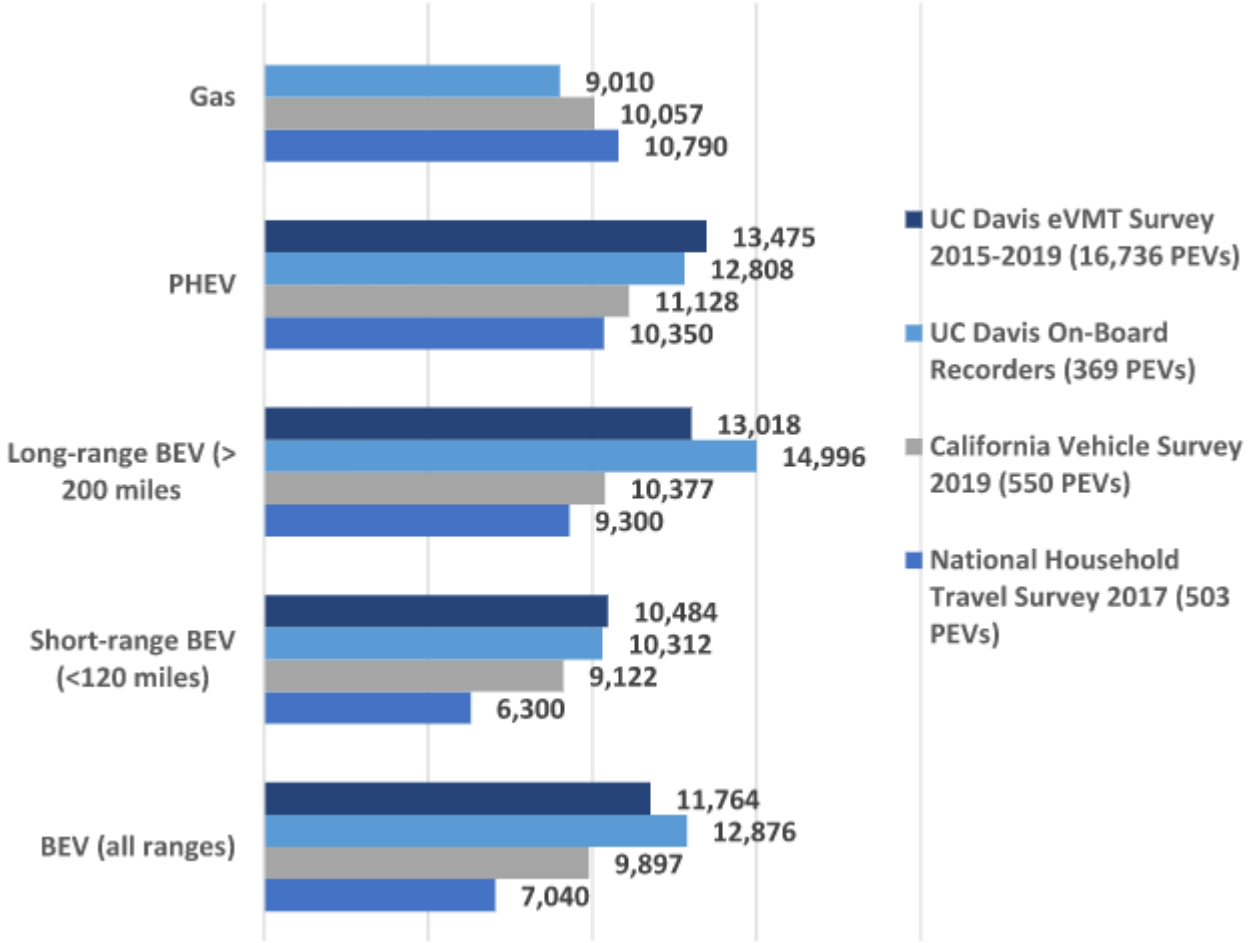
- The use of NHTS and CHTS data in academic research is very prominent!
- Travel behavior is necessary to understand the energy and emissions implications of an electric vehicle transition:
  - How much electricity is needed to charge EVs?
  - How many chargers and where should they be deployed?
  - What are the infrastructure requirements needed for the electricity grid to support the electricity demand?
  - What are the emissions associated with electricity generation upstream?

# NHTS/CHTS and electric vehicles

- How well does NHTS and CHTS represent the behavior of electric vehicle usage in the US and California?
  - Very small sample size of electric vehicles
  - In earlier 2010s, models were essentially restricted to Nissan Leaf, Chevrolet Volt, and Tesla Model S—how representative are these vehicles of more modern EV drivers?
  - How well does the average gasoline vehicle driving behavior represent EV driving behavior?

# How much do EVs drive per year?

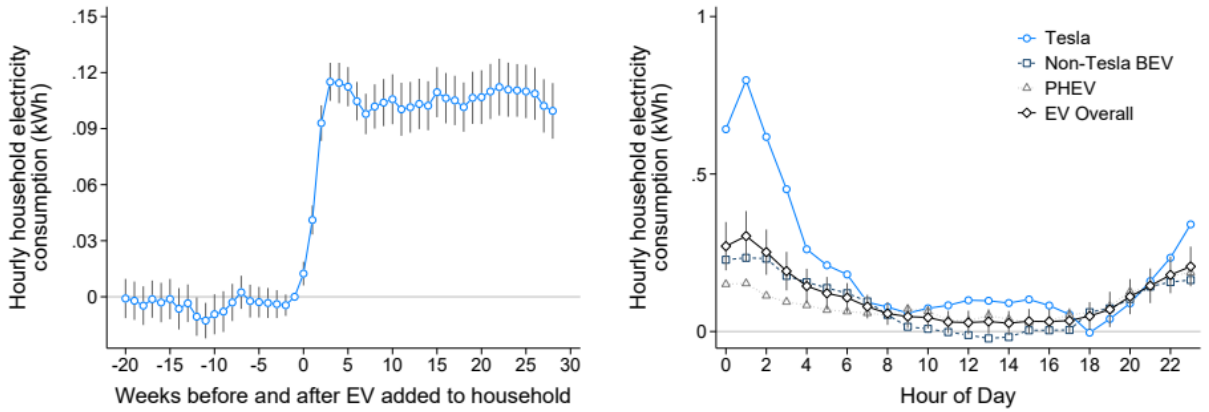
- Fairly large differences in measured travel behavior (as high as ~50% difference!) across different methods
- Why might these differences be happening in the observed data?



# How much do EVs drive per year?

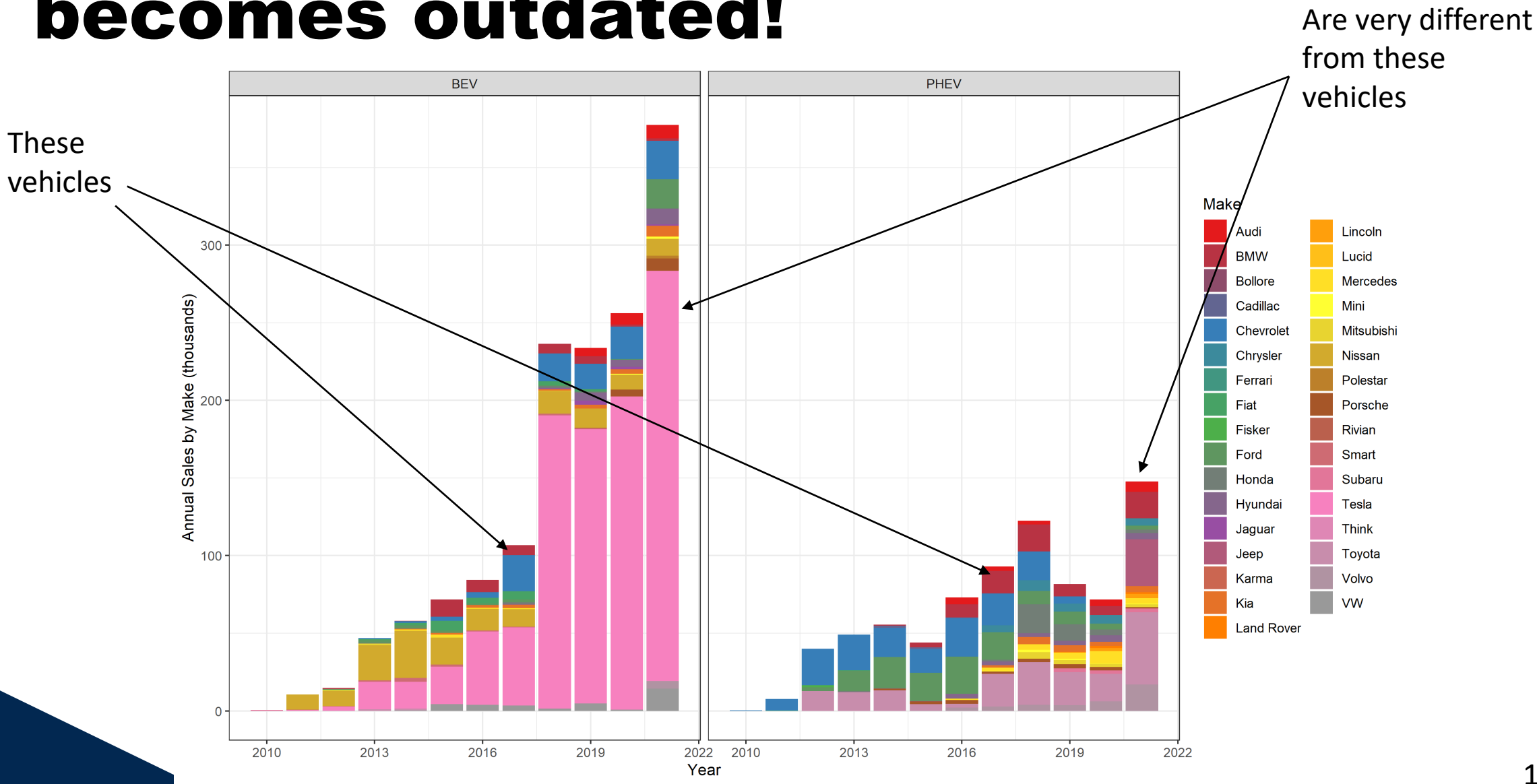
- In a revealed preference study, economists at UC Davis used metered data from PG&E to determine electricity loads before and after acquiring an EV
- The electricity load difference can be used to estimate the amount of electricity going into vehicle charging—and hence the miles travelled

Figure 1: Impacts of EV adoption on household electricity use

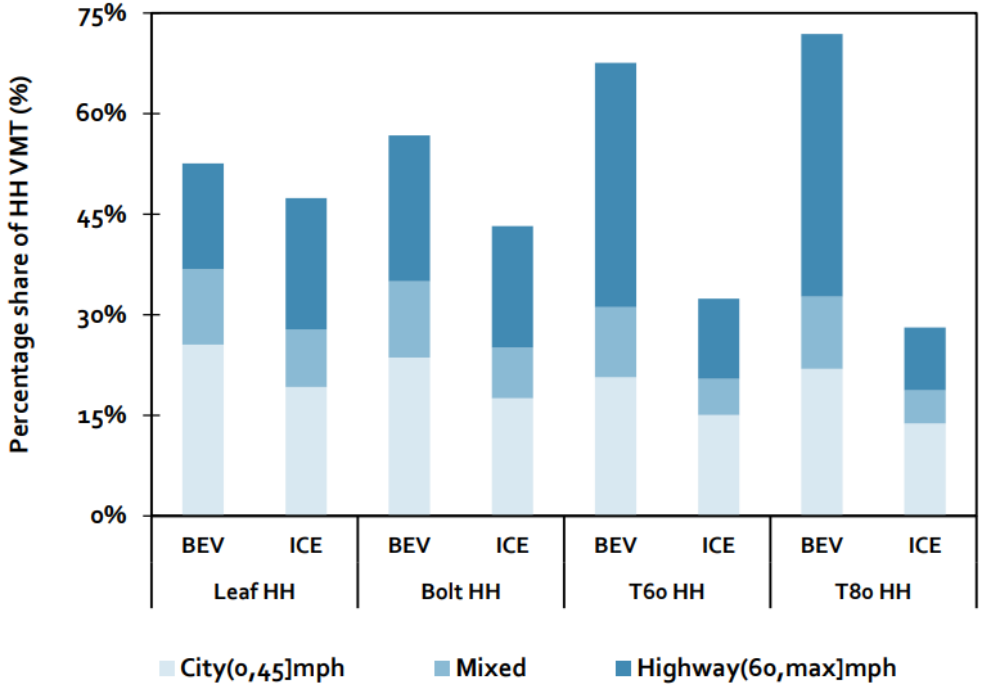


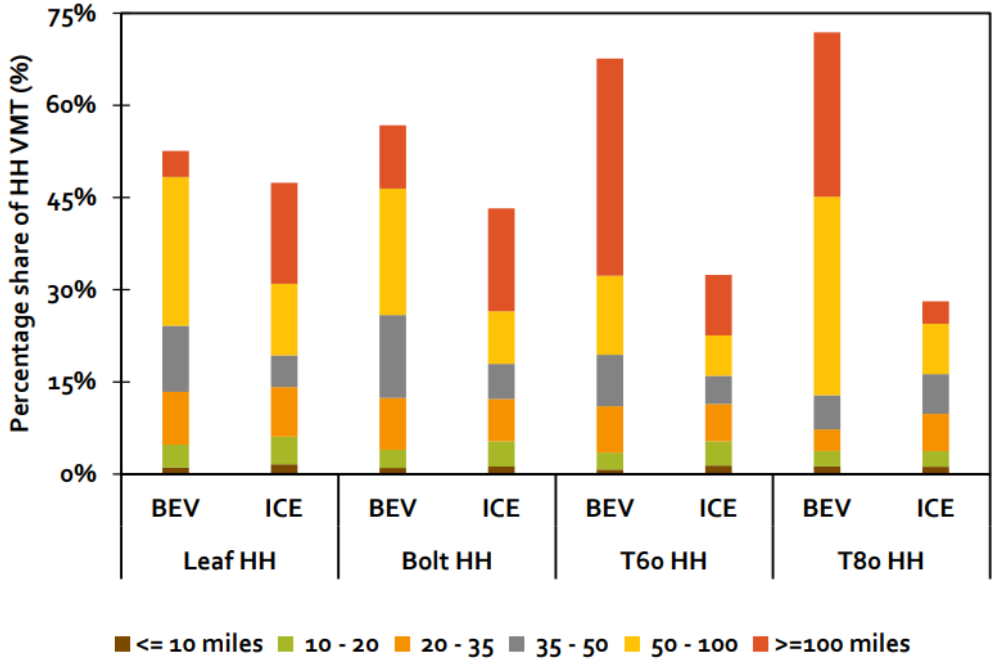

per hour, or 2.9 kWh per day. Given the fleet of EVs in our sample, and correcting for the share of out-of-home charging, this translates to approximately 5,300 electric vehicle miles traveled (eVMT) per year. These estimates are roughly half as large as official EV driving estimates used in regulatory proceedings (see, e.g., California Energy Commission (2019)). The discrepancy between the estimates likely results from selection bias in the

# ...but travel behavior rapidly becomes outdated!



# …and its more complicated than you might think!




- How do 2 car households use their EVs compared to their ICVs?
- More EV range = higher share of household (HH) VMT and larger share of highway and long-distance driving

# Plug-in Hybrid Electric Vehicle Usage

A PHEV's utility factor is defined as

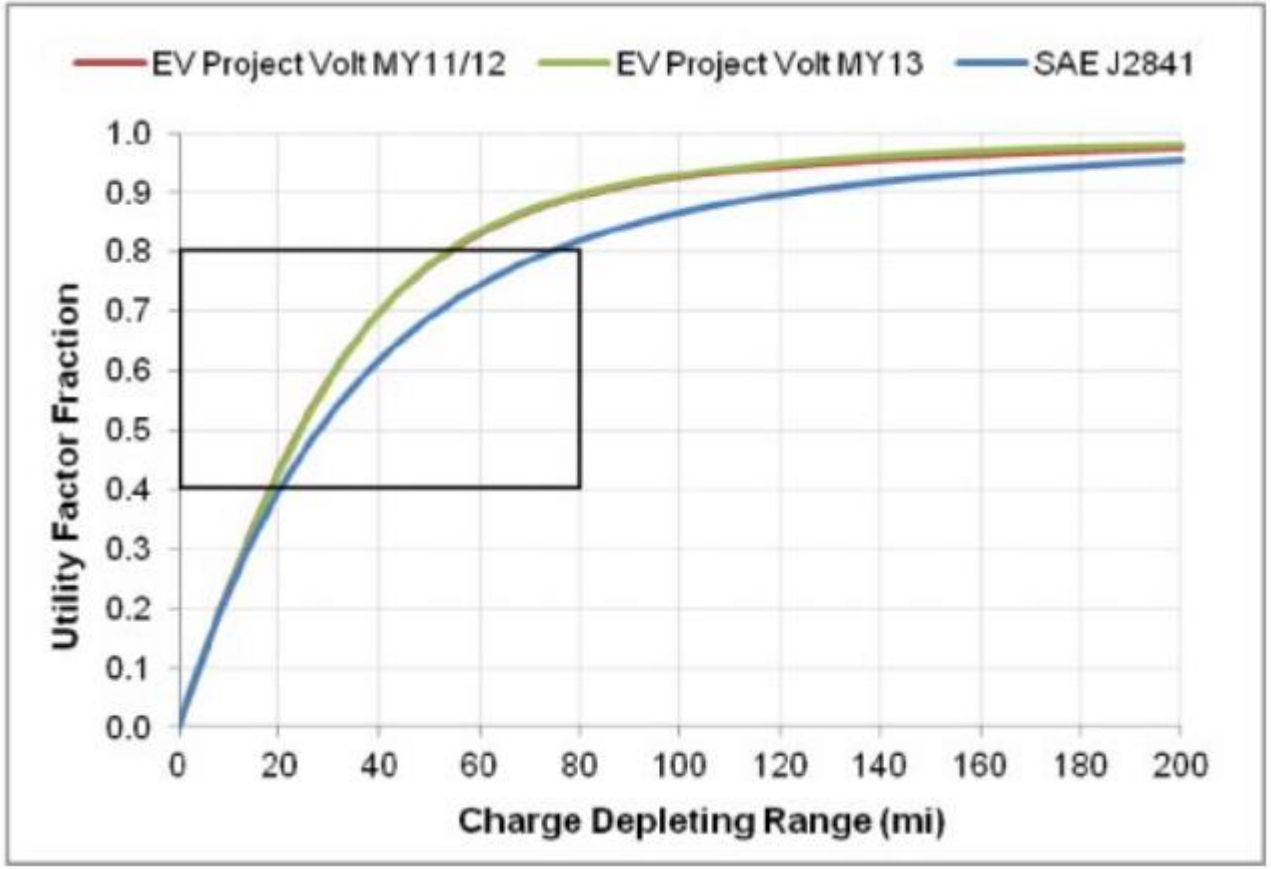
*the proportion of distance traveled in the electric mode*

# How should PHEVs be treated in regulation?

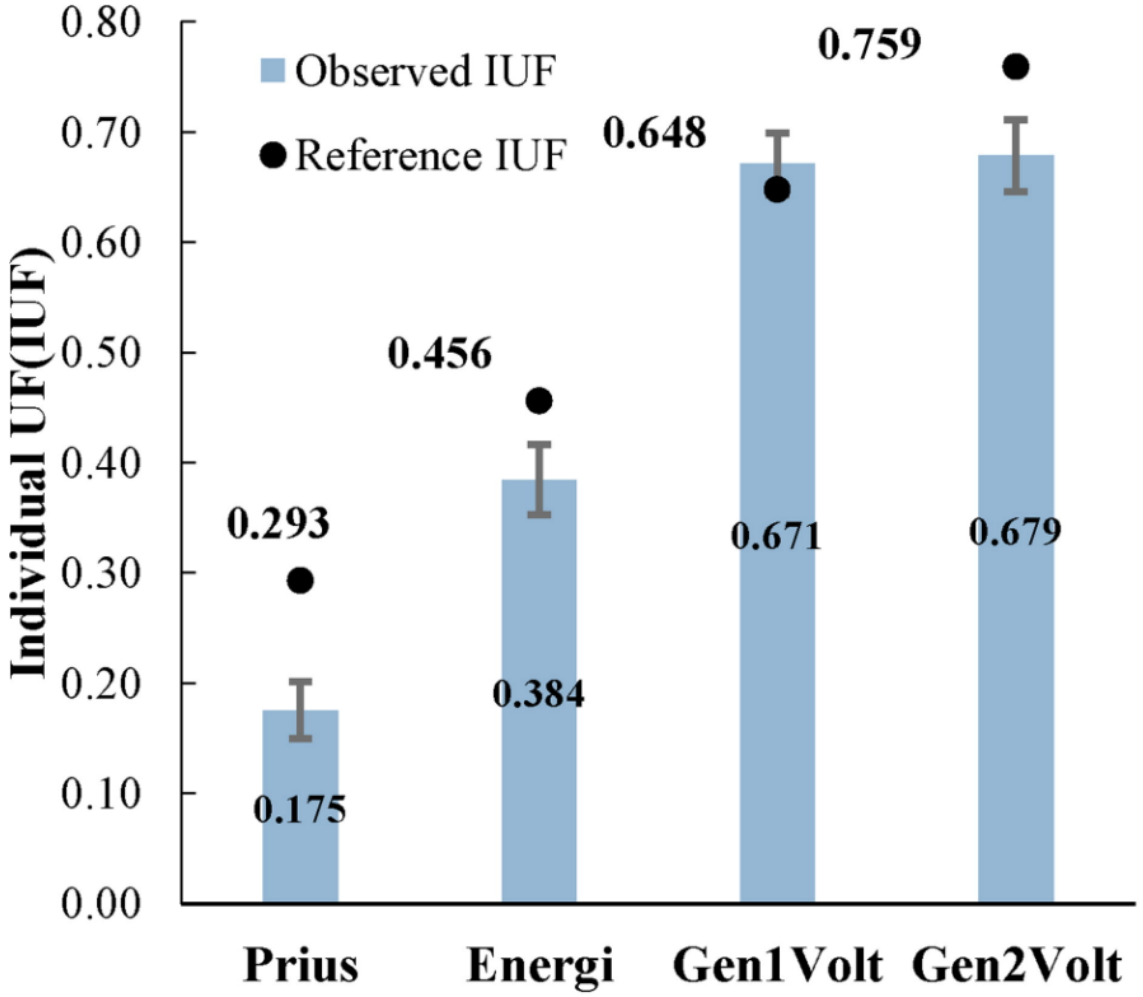
1. The goal of many regulations (in the area of EVs) are ultimately trying to address climate change
2. Promote the adoption of electric vehicles and decrease use of fossil fuels
3. Ideally increase the electric miles driven on the road
    a. How are PHEVs being used?  What is the breakdown of gas vs electric?
    b. Should we treat PHEVs differently if they are driven 50% gas & 50% electric vs 10% gas & 90% electric?

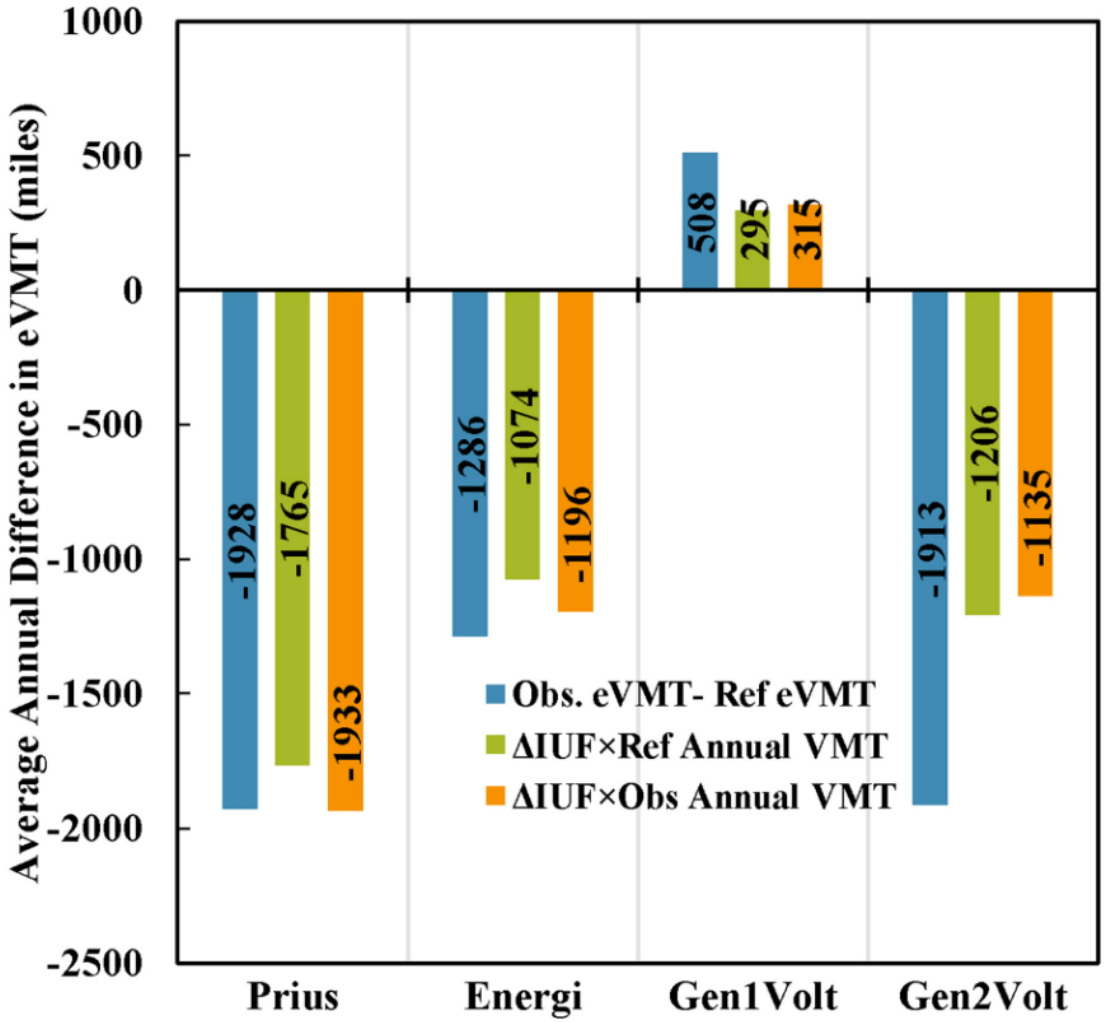
# SAE J2841 Utility Factor

- Determines UF based on a calculation method from travel survey data on conventional fuel vehicles
  - Assumes each vehicle is fully charged at the beginning of the day
  - Assumes each vehicle does not charge until after all of the travel in a given day



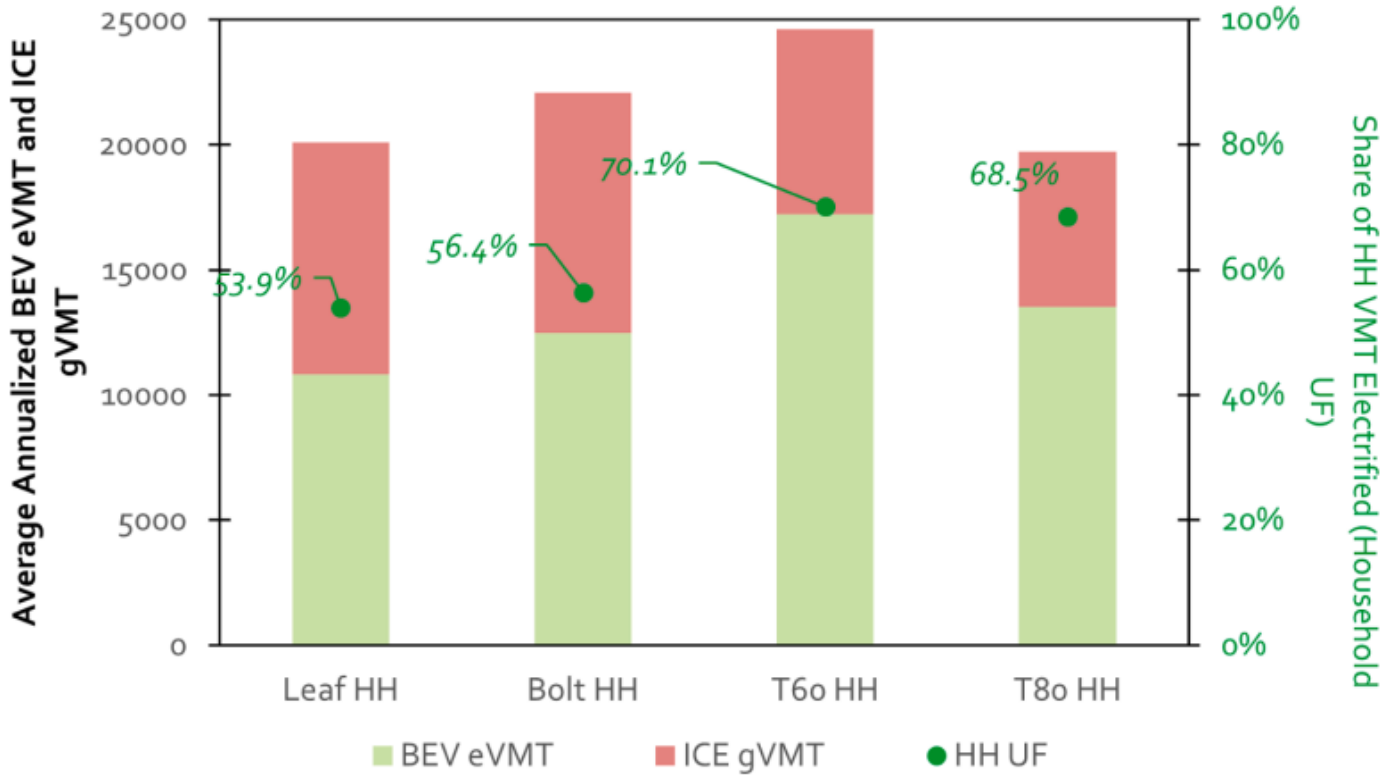
# How does the SAE UF compare to reality?



# How does *household* eVMT change?

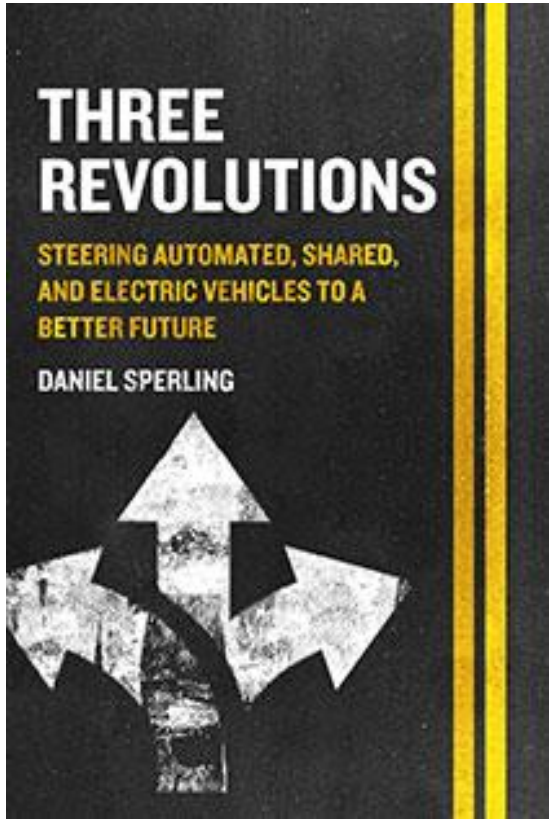
- The issue of PHEV UF can be analogously extended to BEVs as well!
- Consider a household that has a full BEV and a gas car.  How many miles of electric driving vs gas driving are done?



# Transportation Network Companies

# Three Revolutions

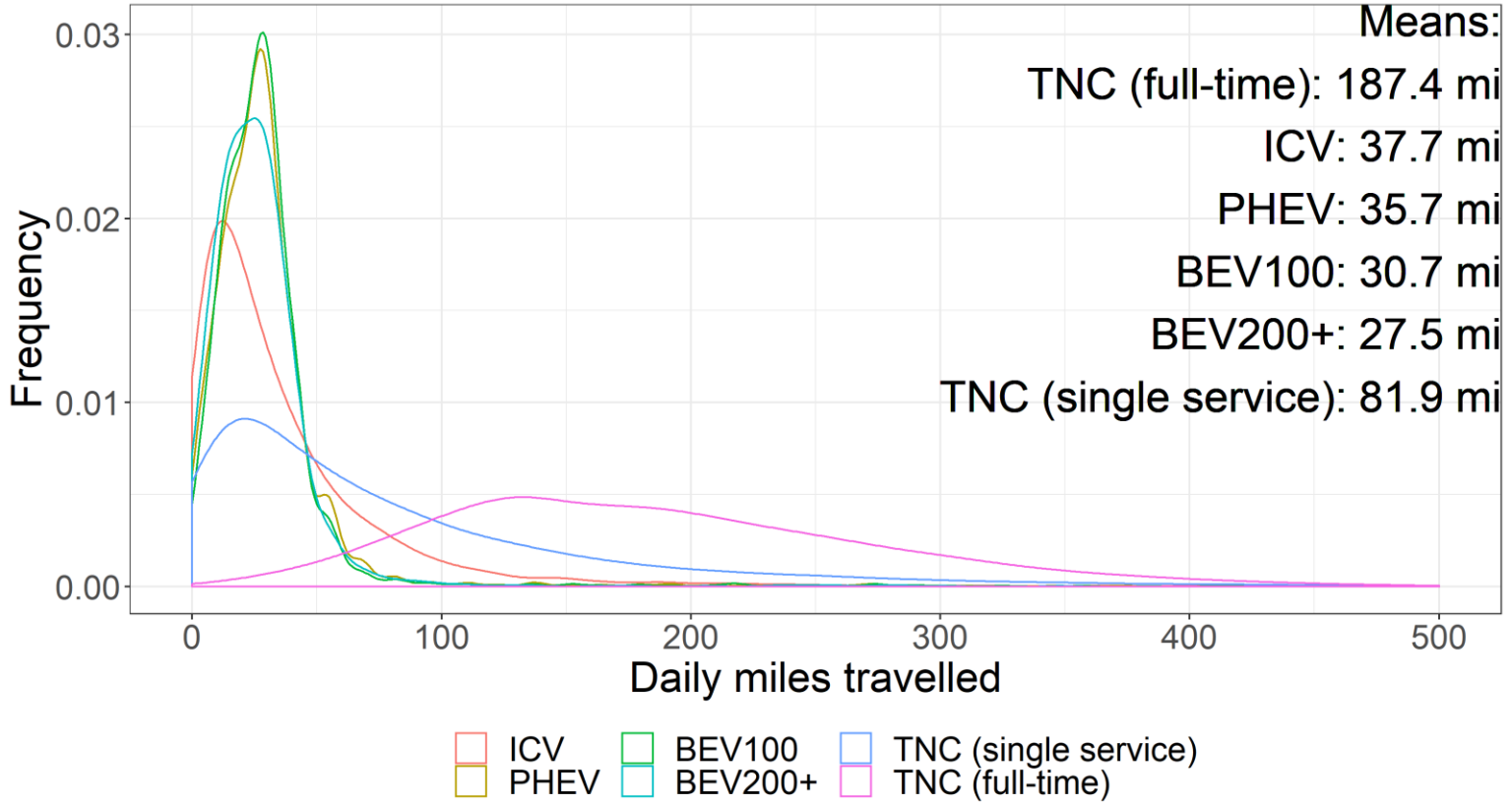
- Consider a transformation of our current transportation system, where all vehicles are:
  - Electric – fully electrified vehicles
  - Shared mobility – all trips are shared and vehicles may not even be personally owned (think Uber and Lyft fleets)
  - Automated – eliminates need to have a driver



# Shared mobility and TNCs

- Transportation network companies – companies that provide transportation services for compensation, usually with online apps or similar platforms
  - Car-sharing – shared use of a vehicle (whether personally-owned or fleet-owned), e.g. ZipCar, Car2Go, GIG Car Share,Turo, etc.
  - Ride-hailing – pre-arranging service rides for a specific transportation trip, e.g. Uber, Lyft,
- Travel behavior for these vehicles is very different!

# Ride-hailing drivers




- While the average driver travels about 30-40 miles per day, full-time drivers for Uber and Lyft are averaging almost 200 miles (!) per day

# EV chargers for Uber and Lyft

- Using trip data from Uber and Lyft, we can determine the best places to install chargers
- Lots of DC fast charging necessary for ride-hailing vehicles!
- Mostly in downtown areas and near the airport