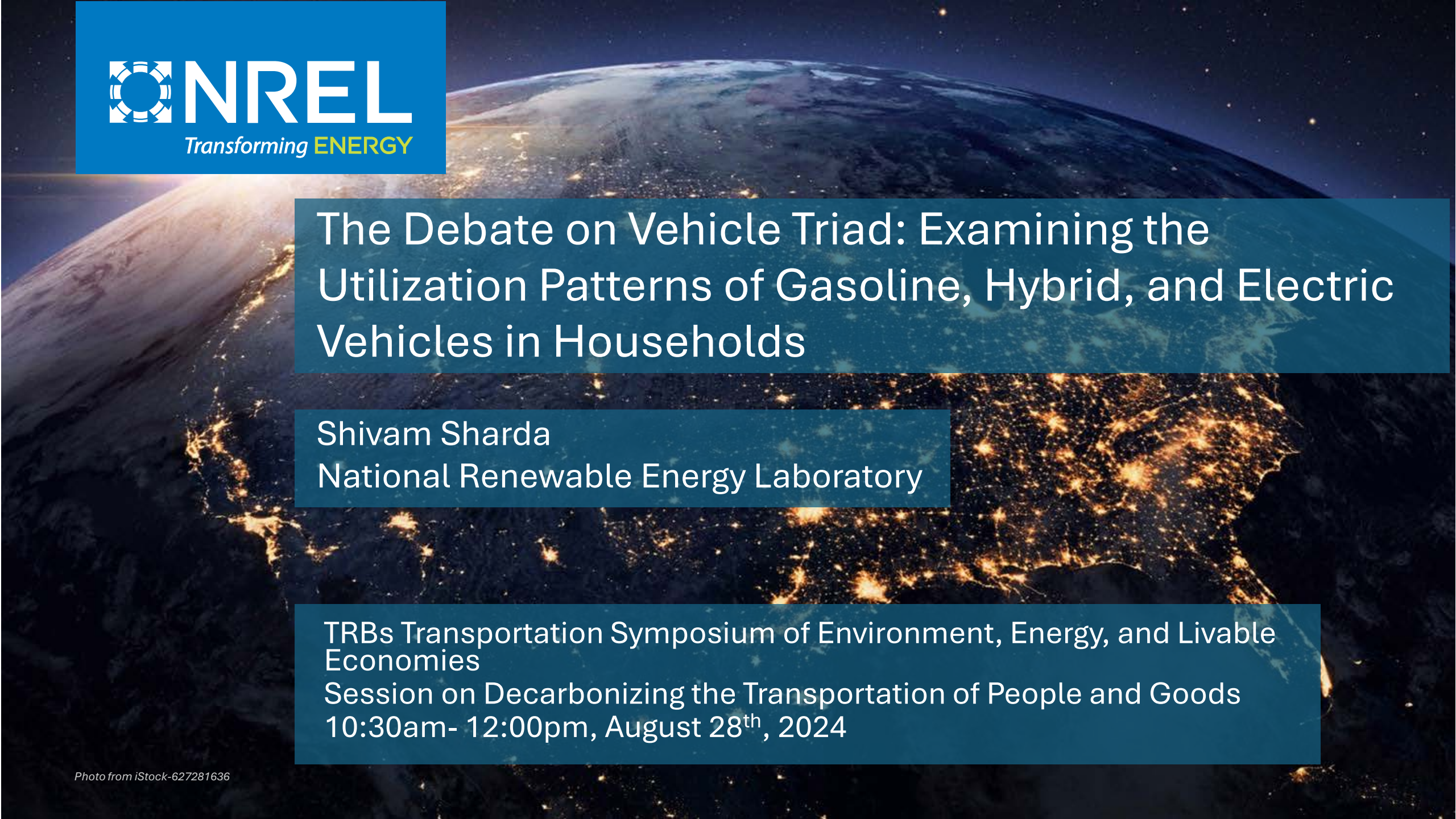

The Debate on Vehicle Triad: Examining the Utilization Patterns of Gasoline, Hybrid, and Electric Vehicles in Households

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National Renewable Energy Laboratory

TRBs Transportation Symposium of Environment, Energy, and Livable Economies
Session on Decarbonizing the Transportation of People and Goods
10:30am- 12:00pm, August 28th, 2024

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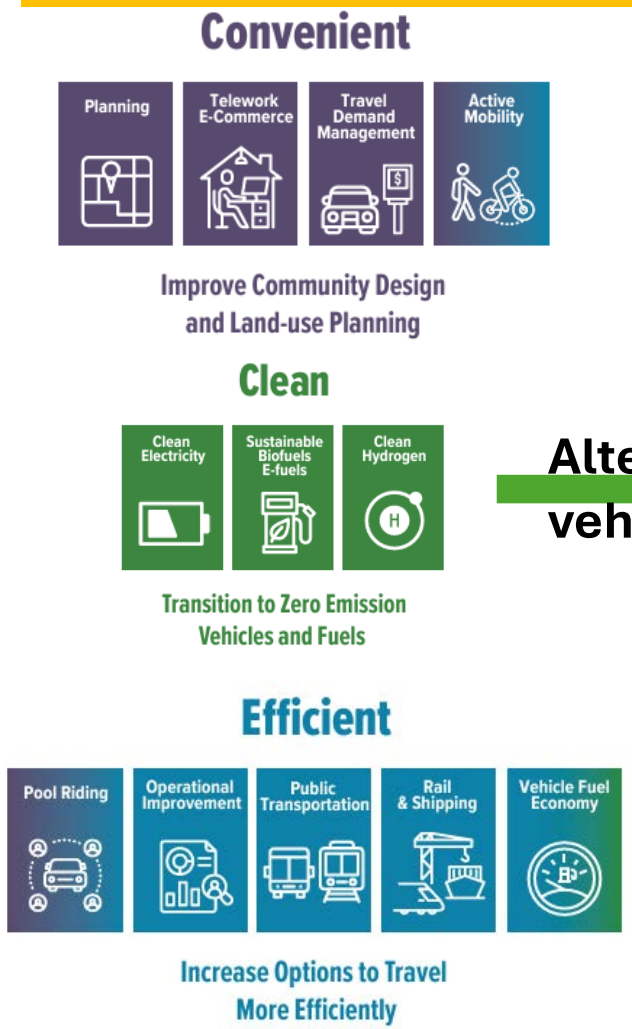
Outline

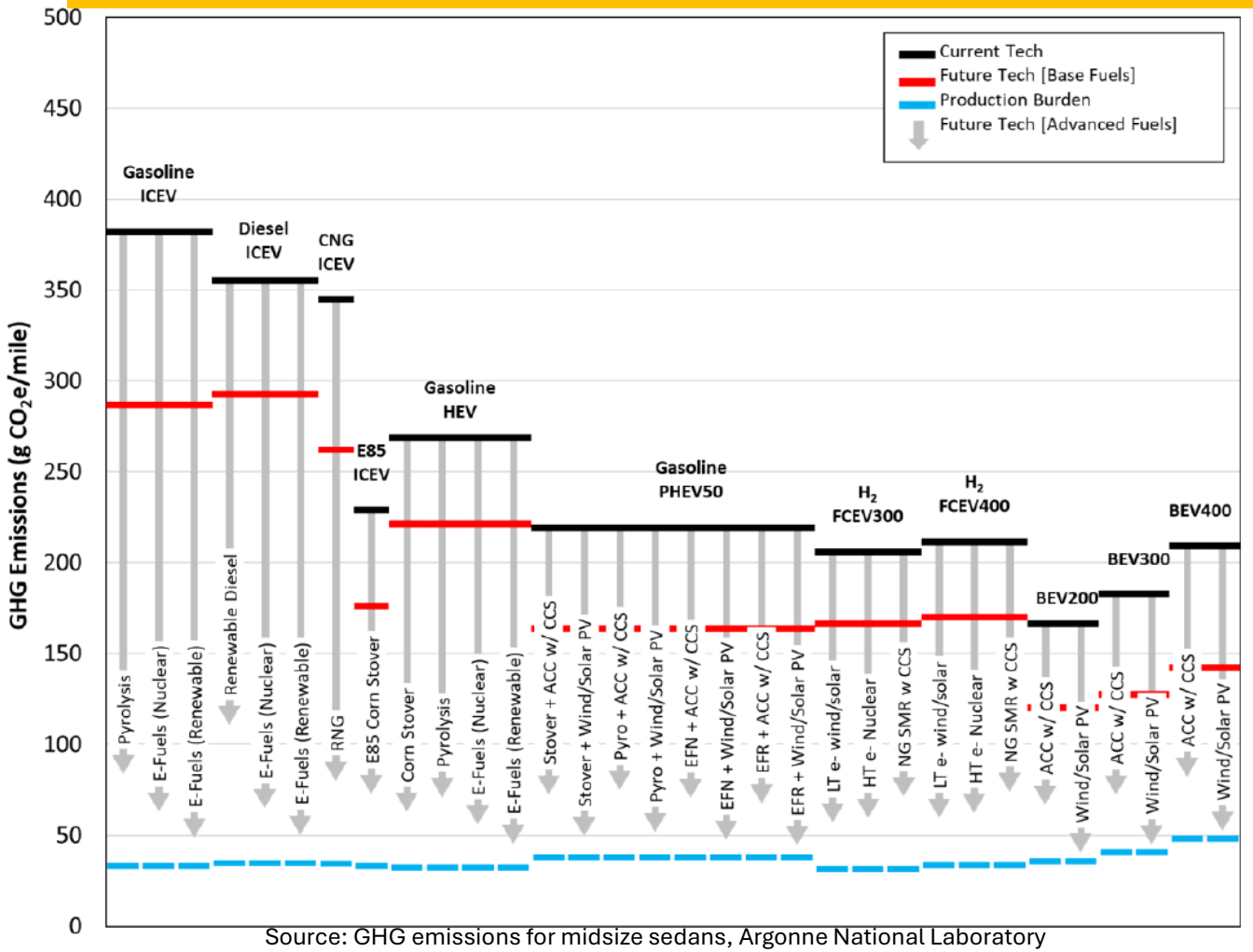
A Key Near-Term Strategy to Reduce Transport Emissions

The U.S. National Blueprint of Transportation Decarbonization Strategies



Alternative fuel vehicles (AFVs)

AFVs have a potential to decarbonize transport sector, if they **replace emissions-intensive vehicle 'utilization'**



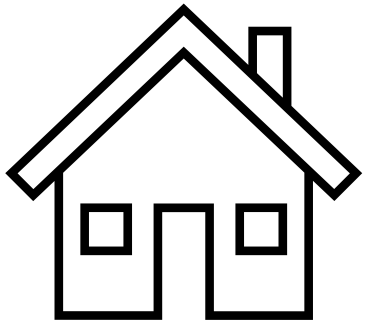
Source: GHG emissions for midsize sedans, Argonne National Laboratory

Households Growing Mixed Vehicle Fuel Type Fleet

Internal Combustion Engine Vehicles (**ICEVs**)

Hybrid Electric Vehicles (**HEVs**)

Electric Vehicles (**EVs**)



Studies have focused on factors influencing household's EV and hybrid vehicle adoption, but **understanding their utilization within households** with mixed vehicle fuel types is crucial to assess their environmental benefits

Picture Source: Google

The Ongoing Debate on Vehicle Utilization Research

Source: Randal Munroe
https://xkcd.com/1285/

Zhao et al (2023) found EVs are driven 4,500 miles per year **fewer than GVs**

Davis (2019) & Burlig et al (2021) found EVs are driven ~3,200 miles per year **fewer than GVs**

Doshi & Metcalf (2023) found EVs with >100-mile range **driven same as GVs**

Chakraborty et al (2022) from survey of CA EV owners reports EVs **driven more** than GVs

The continuing debate underscores the importance of **leveraging latest dataset** to enhance our understanding on how advancements in electrification technology would **shape travel behaviors**

Determinants of Vehicle Miles Traveled in Household

- Studies have focused on understanding factors influencing total VMT

  - Socio-demographic variables
  - Built environment attributes
  - Self-selection effect

  } Explained 56% of total household VMT variance (Singh et al, 2018)

  - Ownership of gasoline-electric hybrid vehicles
  - Battery range
  - Home access to level 2 charging
  - Solar panel installation

  } Lead to an increase in annual household VMT and household EV utilization (Sun et al, 2019 ; Jia et al, 2022)

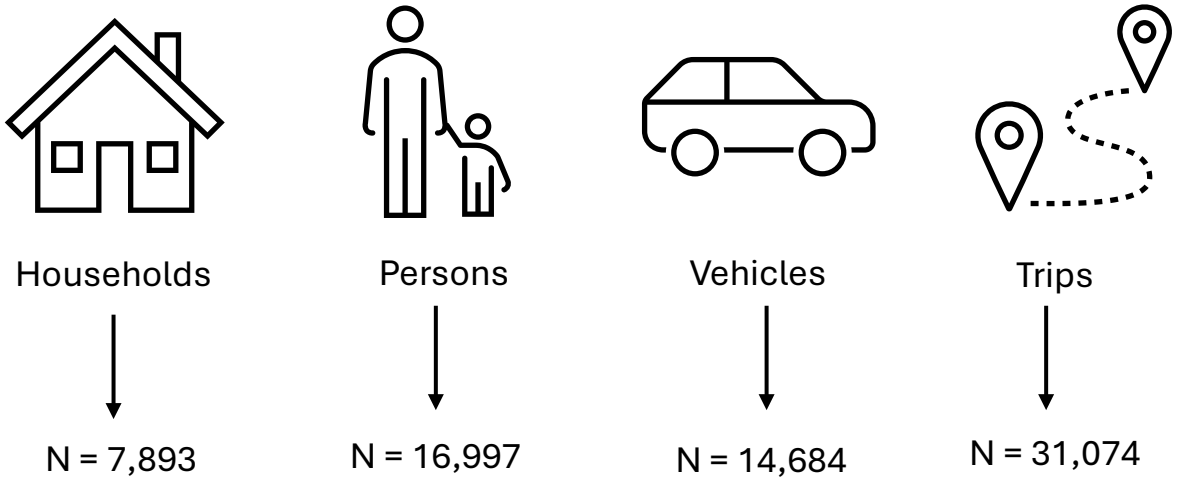
While these studies offer insights into determinants of household VMT, this study focuses on how households make deliberate choices to allocate miles to different vehicle fuel types

Research Objective

Determine whether electric vehicles (EVs) and hybrid vehicles (HVs), including plug-in hybrid electric vehicles, **are driven less than, as much as, or more than gas vehicles** (GVs)

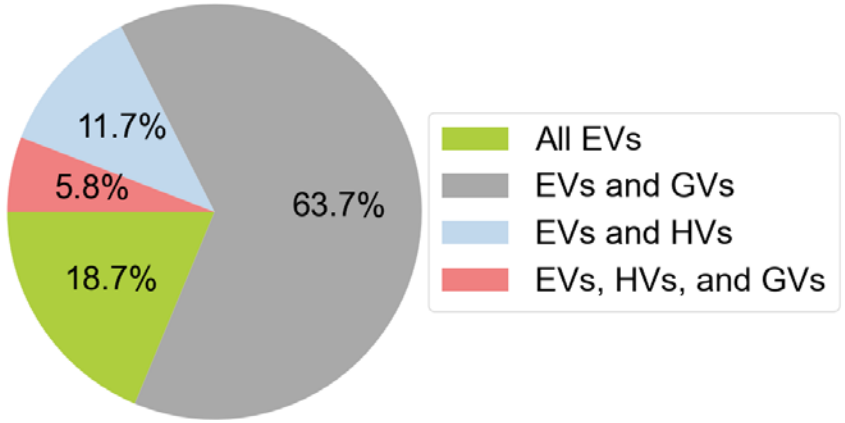
Explore **household characteristics influencing** fuel-type choices, and whether electric vehicles, hybrid vehicles, and plug-in hybrid electric vehicles **substitute or complement** gas vehicle use in a household

2022 National Household Travel Survey



After extensive cleaning, **about 150 households** were found to own **at least one electric vehicle** which comprised the estimation sample

Household fleet composition in households with at least 1 EV: 2022 NHTS



Seemingly Unrelated Regression (SUR) Model

The general form of i^{th} equations is given as:

$$y_{ij} = X_{ij}\beta_{ij} + \varepsilon_{ij}, \qquad j = 1,2,\ldots\ldots,l \quad and \quad i = 1,2,\ldots\ldots\ldots\ldots,N$$

$$\begin{bmatrix} y_1 \\ \vdots \\ y_l \end{bmatrix} = \begin{bmatrix} X_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & X_l \end{bmatrix} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_l \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_l \end{bmatrix}$$

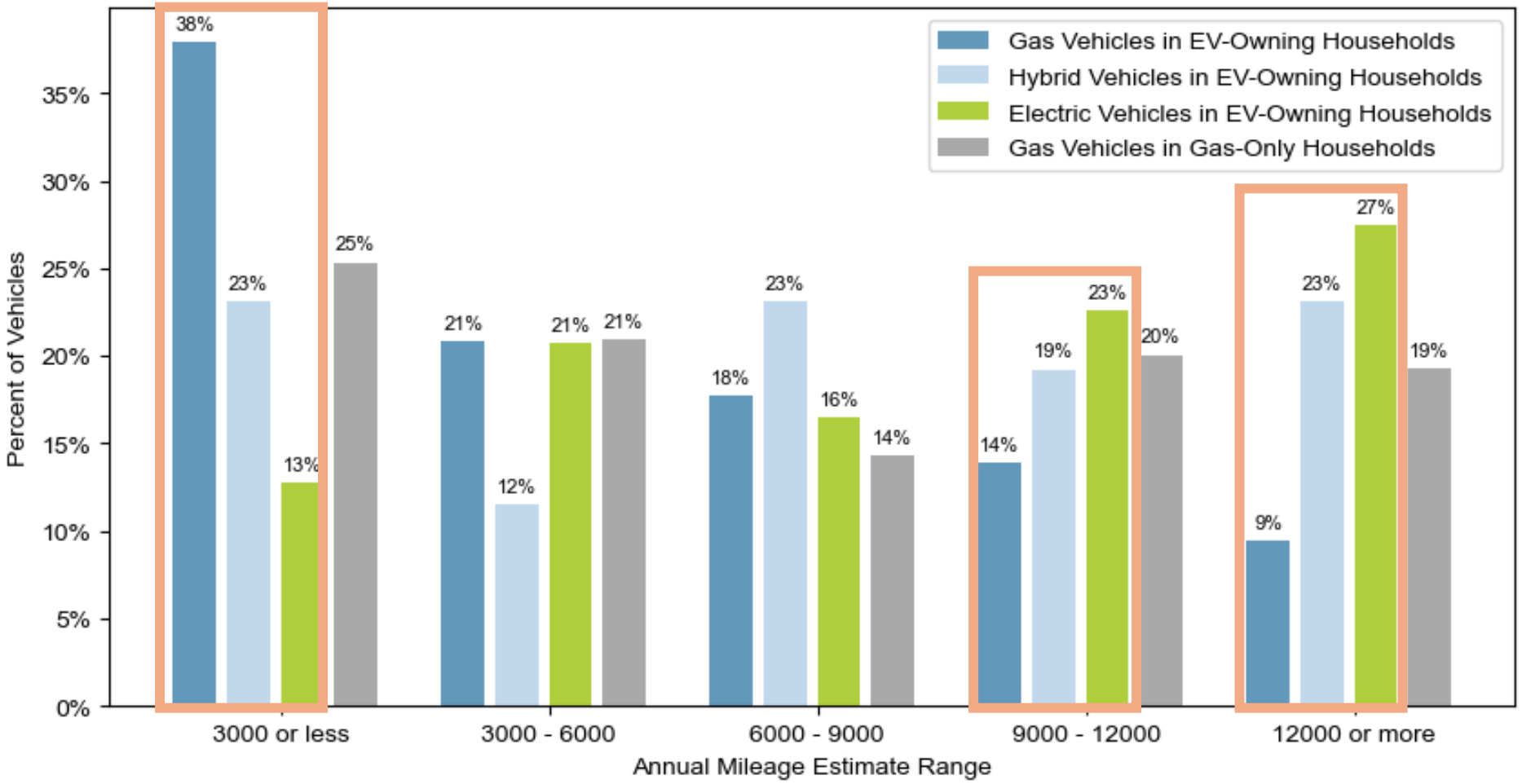
The variance-covariance matrix can be written as:

$$\Sigma = \begin{bmatrix} \sigma_{GV,GV} & \sigma_{GV,EV} & \sigma_{GV,HV} \\ \sigma_{EV,GV} & \sigma_{EV,EV} & \sigma_{EV,HV} \\ \sigma_{HV,GV} & \sigma_{HV,EV} & \sigma_{HV,HV} \end{bmatrix}$$

The error correlation provides insights into the **substitution** and/or **complementarity** trends between **vehicle fuel-types use within households**

Visualization of Annual Mileage Distribution at the Vehicle Level

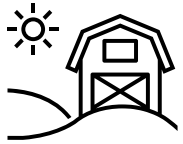
EVs are ***utilized as much as GVs*** (over 3,000 annual miles), reinforcing findings by Chakraborty et al. (2022) and Tal et al. (2020)



- A higher percentage of **GVs belong to lower annual mileage bins**, with a steady decrease towards higher mileage bins
- HVs **do not show a consistent trend** but are in higher percentages in bins with annual mileage greater than 6000, compared to GVs

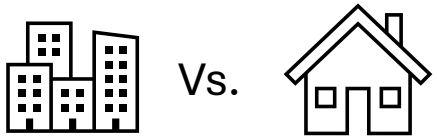
Determinants of Gas Vehicles (GVs), Electric Vehicles (EVs), & Hybrid Vehicles (HVs) Utilization

Household Location



Rural households have **higher EV and HV use**

Home Unit Type

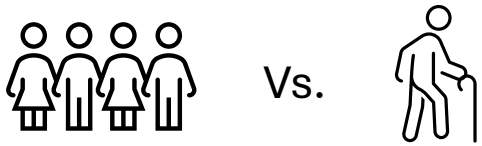


Detached housing units are correlated with **higher GV use** and **lower EV use**

Number of Workers in Household

Associated with **higher GV and EV use**

Generational Differences



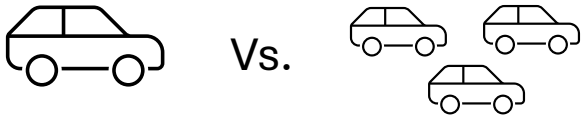
Higher younger-people count is correlated with **higher EV use**

Higher older-adults count is correlated with **higher GV and HV use**

Work From Home

Households with **more people working from home** have **lower GV and HV use**

Vehicle Ownership



Higher vehicle count is correlated with **higher GV use** and **lower EV use**

Substitution / Complementarity

Greater EV, HV use is correlated with **less GV use**

Greater **EV and HV use are correlated**

Conclusions and Implications

- The study explored the **utilization patterns of multiple fuel types** among EV owning households, while accounting for substitution and complementarity effects

- The findings indicated that **households that own EVs are using them in place of GVs** to fulfill their travel needs, with HVs showing a similar trend.

- EVs are **utilized as much as GVs**, reinforcing findings by Chakraborty et al. (2022) and Tal et al. (2020)

- These findings can inform development of emerging policies such as mileage-based user fees, predict electricity demand, and optimize energy distribution

Limitations and Future work

- Use bigger samples, the **NHTS sample of 150 households** is too small to generalize the results, suggesting **caution during interpretation**
- Explore **advanced models** such as Multiple Discrete Continuous Extreme Value (MDCEV) to explore nuanced satisfaction levels with various mobility technologies
- The interplay of **vehicle age and EV range** should be explored to unravel the extent of its influence on electric vehicle miles traveled

Thank you!

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