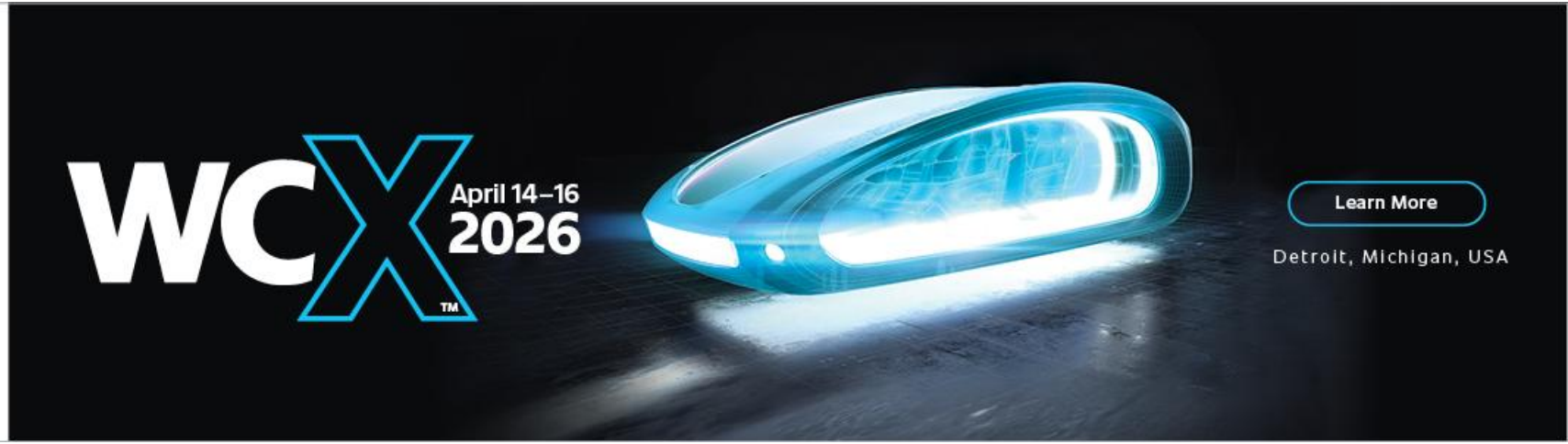
SAE INTERNATIONAL



Identifying Patterns of Real-World Charging Frequency for a Sample of Plug-in Hybrid Electric Vehicles in North America

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TOYOTA

Agenda

- Background
- Approach
- Results
- Conclusions & Future Work

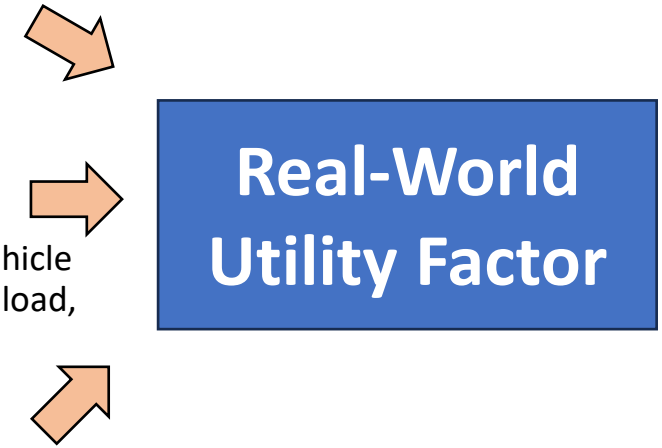
Background: Plug-in Hybrid Electric Vehicles (PHEVs)

Factors Affecting Real World PHEV UF*

1. **Daily VMT**
2. ***Attained* Range**

(Effect of Temperature, Vehicle & Road Conditions, Cargo load, …etc.)

3. **Charging**

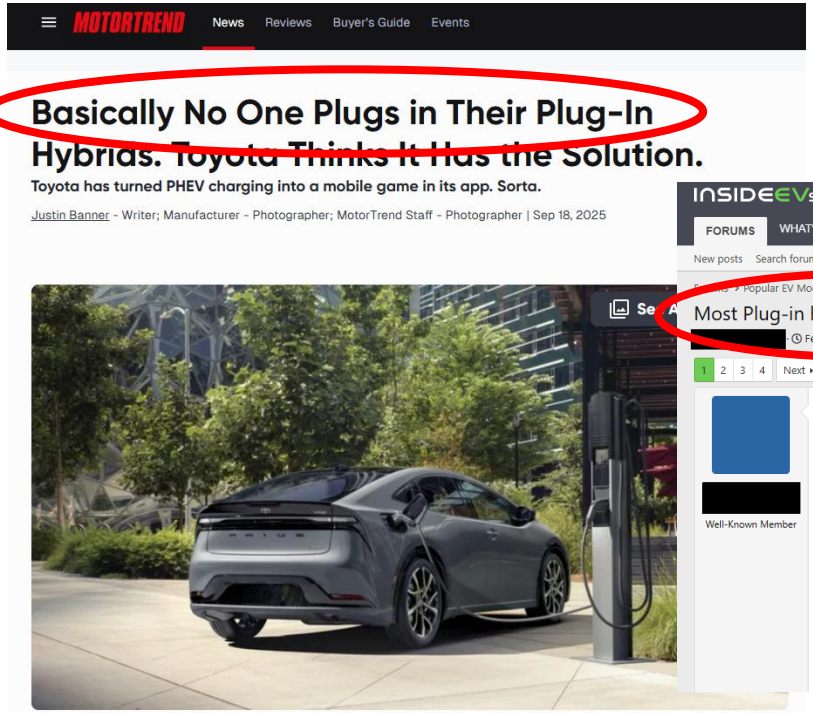


- ***Daily VMT*** obvious that driving more days with distance longer than Electric Range (or days with significant VMT, such as road trips) will reduce the real-world UF
- ***Attained Electric Range**** known that increased load (HVAC, extra cargo, towing, …etc.) or lower battery efficiency in cold weather, reduces the attainable electric range
- ***Charging*** is the focus of this study

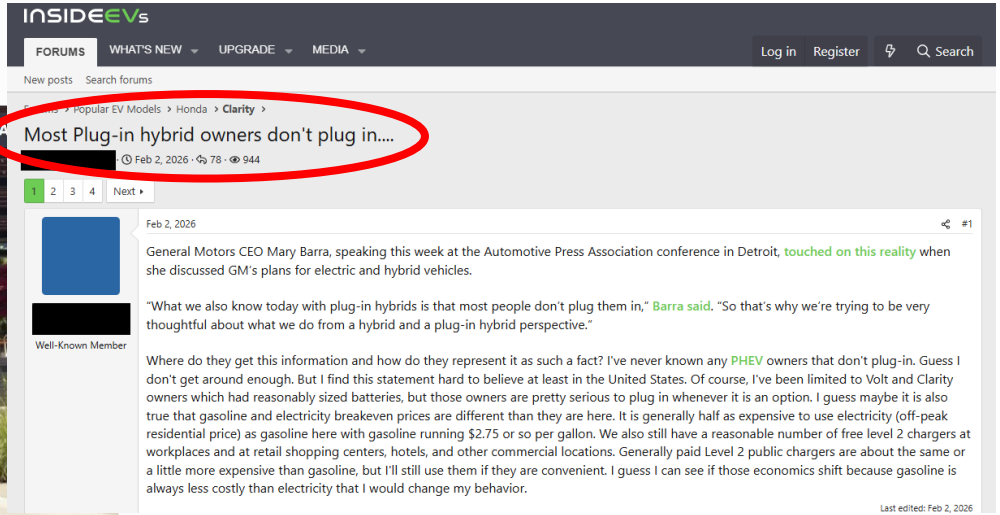
* https://doi.org/10.3390/wevj15100458

** Parker et. al. ***Extreme Heat Effects on Electric Vehicle Energy Utilization and Driving Range***. Applied Energy **380**: 125051

Background: Perceptions about PHEVs



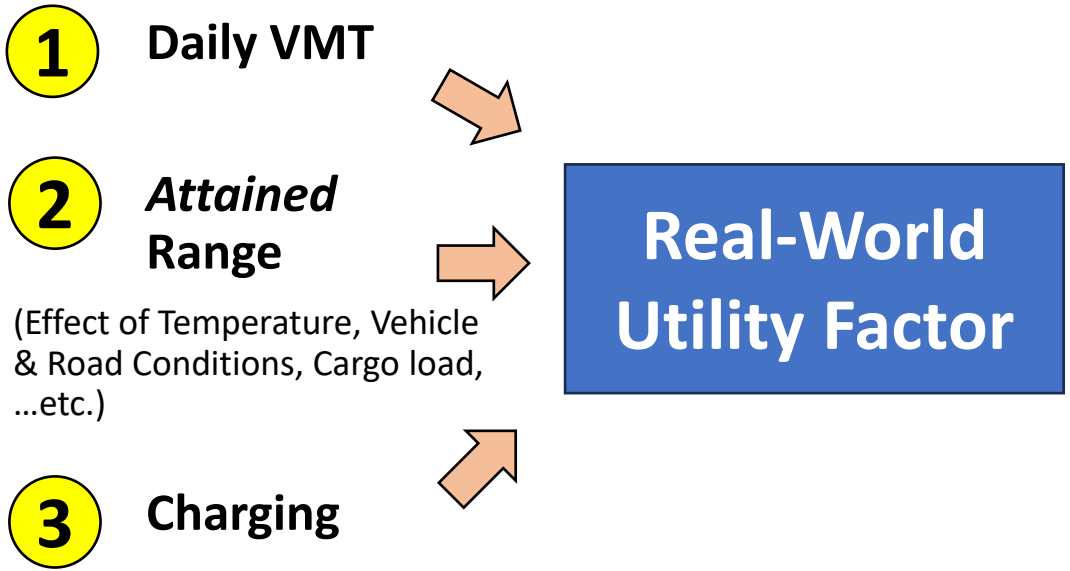
https://www.motortrend.com/news/toyota-plug-in-hybrid-charging-phev-game-app



https://www.insideevsforum.com/community/threads/most-plug-in-hybrid-owners-dont-plug-in.20818/

Background: Key Question

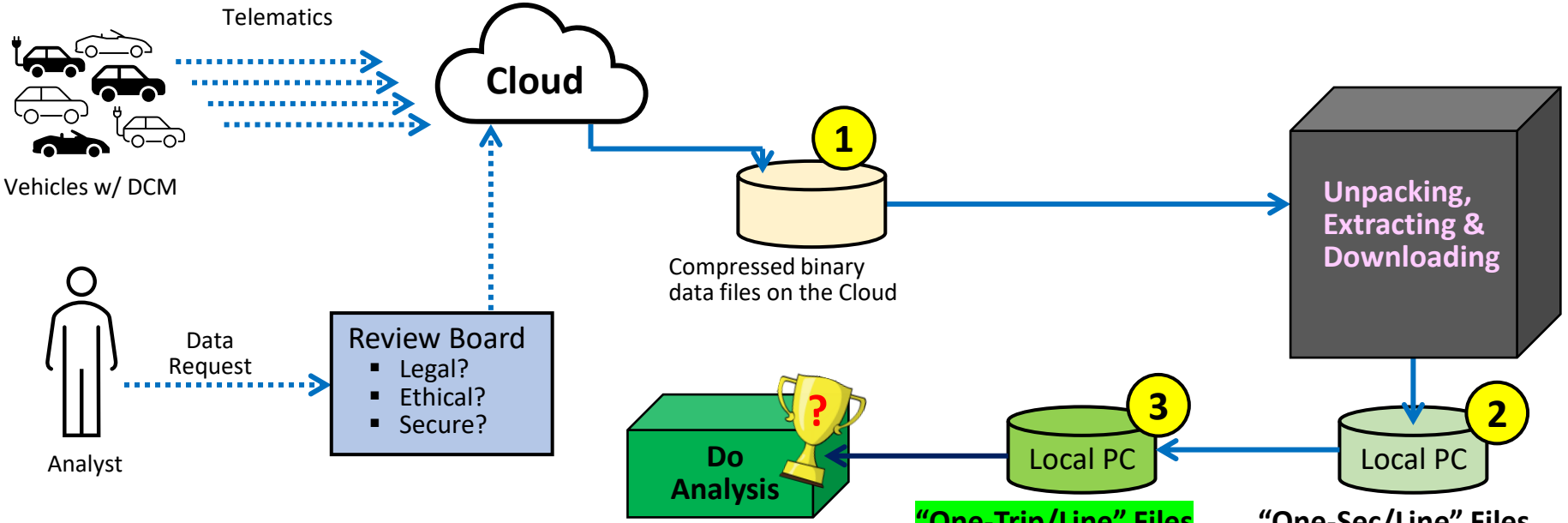
Factors Affecting Real World PHEV UF



- ***Daily VMT*** obvious that driving more days with distance longer than Electric Range (or days with significant VMT, such as road trips) will reduce the real-world UF
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Are PHEVs being Charged?

Approach: Acquisition & Analysis of Vehicle Telematics Data



"One-Trip/Line" Files

- Comma-separated value (CSV) text files
- **One line summary per one whole trip** of a vehicle
- Data of multiple vehicles within one file
- **One file per data logging period of one Model**

"One-Sec/Line" Files

- Comma-separated value (CSV) text files
- **One data file per vehicle**
- **One line per one second** of vehicle real time
- Dozen (or so) data fields per line

Approach: Detecting Charging Events & Non-Charging

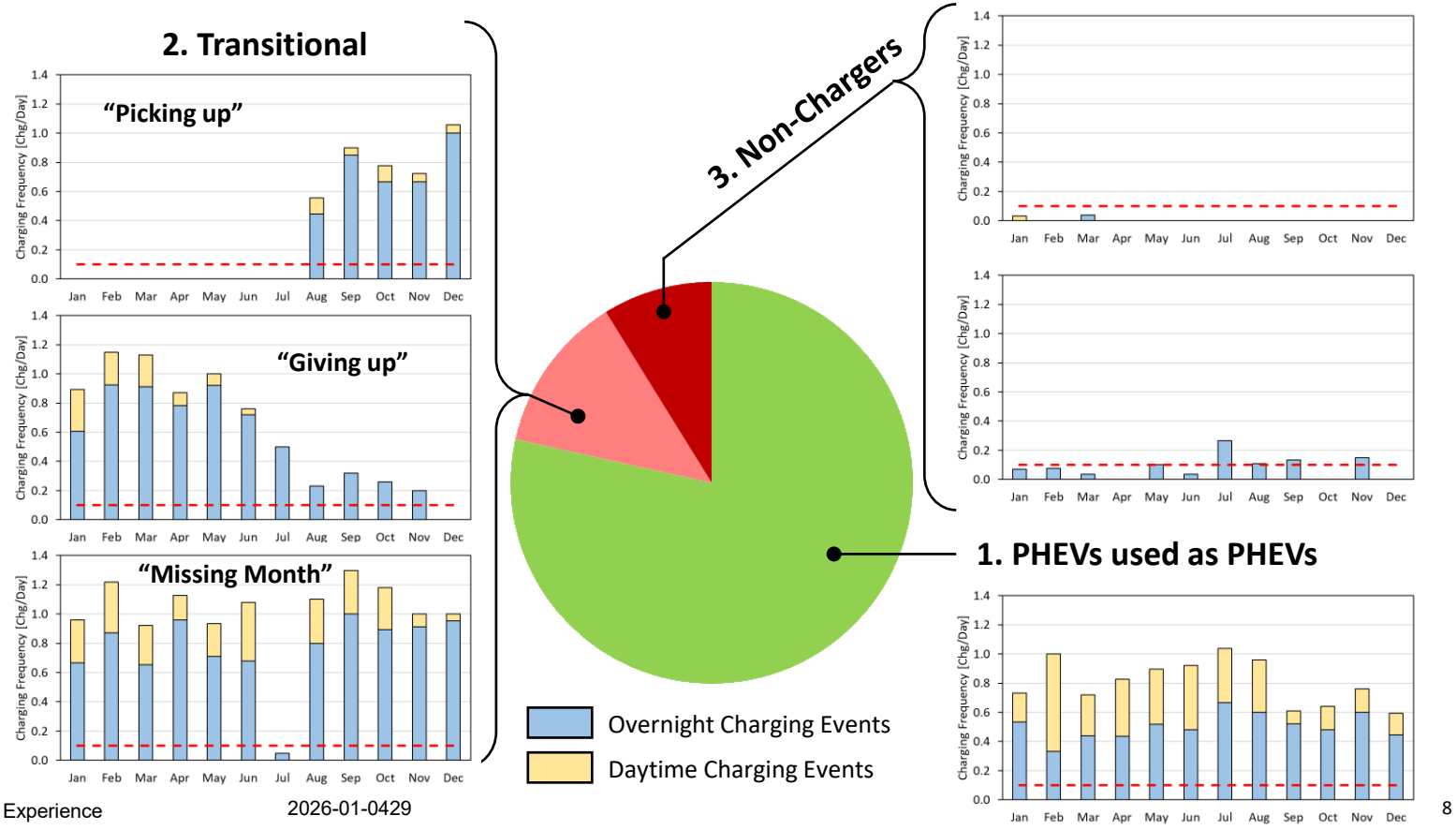
- Telematics Vehicle Data may not include Charging Event Information but one could ***Infer*** the ***Occurrence*** of a **Charging Event** from observing an **Increase in** the Battery State of Charge **(SOC) in-between trips**

- Using trip **time signatures**, one could
  - Calculate the "***Frequency of Charging***" as the **Number of Charging Events per Driving Day**
  - **Distinguish "Overnight Charging"** (Happens between last trip of a day and first trip of next day) **from "Daytime Charging"**

- We also consider a **Threshold* for Low Frequency Charging** (observed over some period of time), **below-which**, we label the vehicle as Vehicle Consistently Not Charged, or "Non-Charger"

* In current work, this threshold is set at **One Charging Event per Ten Drive Days**, but this can be a sensitivity parameter

Approach: Three Classification Groups

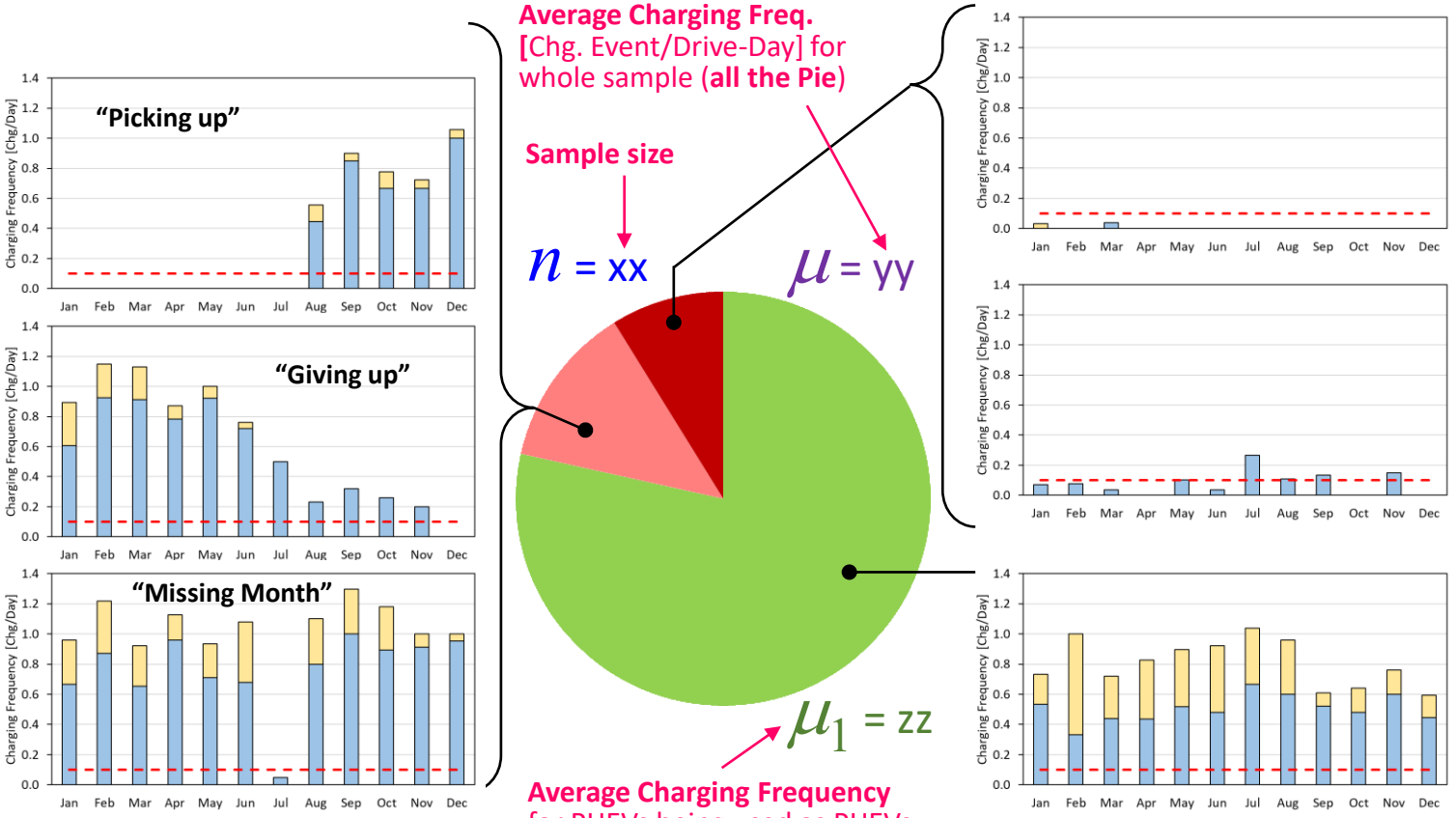


Approach: Real-World PHEVs Sample

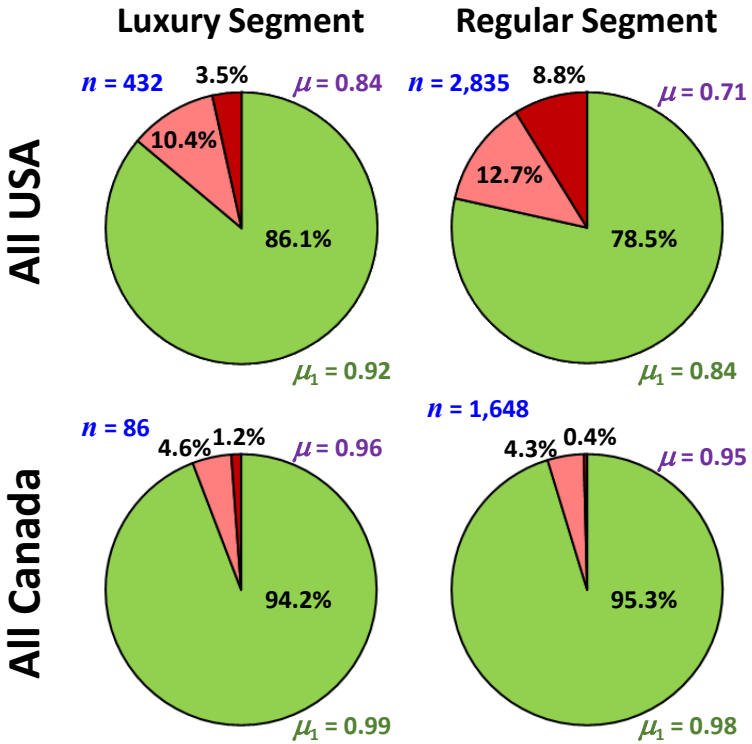
- Random Sample in USA & Canada
- Full Calendar Year 2024
- Small SUV Size Category PHEVs

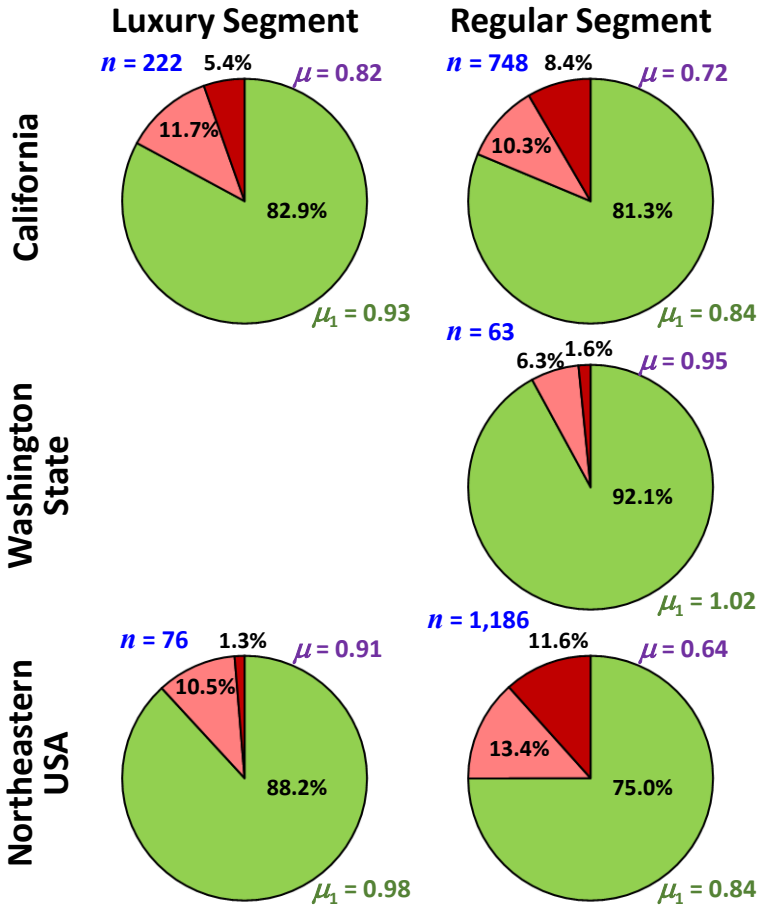
Sample Size n in	Luxury	Regular
USA	432	2,835
Canada	86	1,648

Approach: Additional Metrics & Data Labeling



Results


Luxury Segment
Regular Segment
All USA
n = 432
3.5%
μ = 0.84
10.4%
86.1%
μ1 = 0.92
n = 2,835
8.8%
μ = 0.71
12.7%
78.5%
μ1 = 0.84
All Canada
n = 86
4.6%
1.2%
μ = 0.96
94.2%
μ1 = 0.99
n = 1,648
4.3%
0.4%
μ = 0.95
95.3%
μ1 = 0.98


Luxury Segment
Regular Segment
California
n = 222
5.4%
μ = 0.82
11.7%
82.9%
μ1 = 0.93
n = 748
8.4%
μ = 0.72
10.3%
81.3%
μ1 = 0.84
Washington State
n = 63
6.3%
1.6%
μ = 0.95
92.1%
μ1 = 1.02
Northeastern USA
n = 76
1.3%
μ = 0.91
10.5%
88.2%
μ1 = 0.98
n = 1,186
11.6%
μ = 0.64
13.4%
75.0%
μ1 = 0.84

Conclusions

- The dominant/super-majority behavior for the Observed sample of PHEVs in USA and Canada is ***PHEVs being Used as PHEVs***
- In **USA**, ~2% to ~12% are Non-Chargers, varies by State/Region
- In **Canada**, only ~1% are Non-Chargers

Future Work

- Studying relationships between Charging Behavior, Cost of Gasoline & Electricity & Access to Charging

Contact Information

Disclaimer: The research and expressed opinions in this work are solely those of the authors, not necessarily representative of their Organizations

Thank you!

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