6/21/2022

TRACKING EVOLUTION OF ELECTRIC VEHICLES AND NEW MOBILITY TECHNOLOGY

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VAN032

OVERVIEW

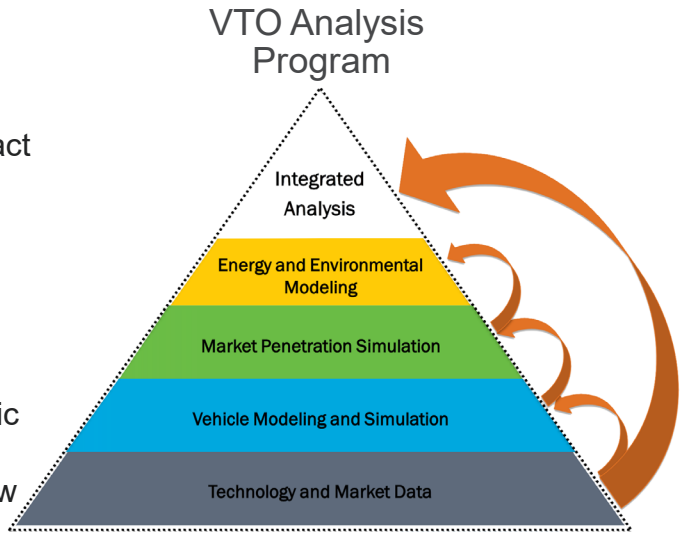
Timeline	Barriers Addressed
• Project start date: 10/01/2019 • Project end date: 09/30/2022 • Percent complete: 90%	• Provide quality data and information regarding electrification and new mobility technologies • Provide both quick responses to internal and external queries and develop summary reports to VTO
Budget	**Partners/Collaborators**
• Total Project Funding: $600 K • Funding for FY22: $200 K	• National labs: ORNL provides EV data • Interact with regional agencies collecting mobility usage data

RELEVANCE AND OBJECTIVES

To better inform VTO analysis, analysis-supported activities, and associated stakeholders

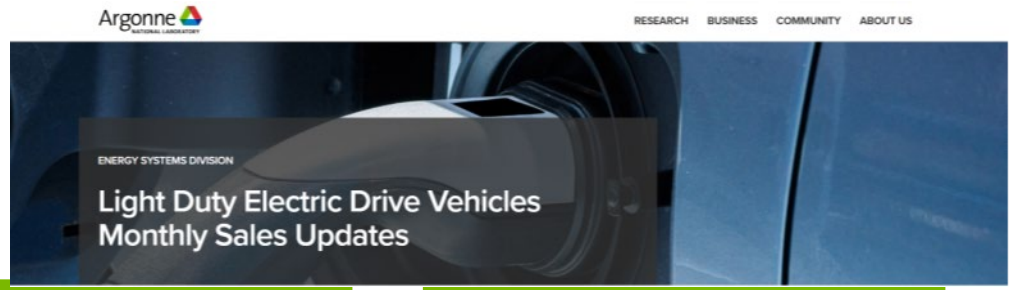
Objectives: Synthesize and improve upon existing data for electrification and mobility technologies to evaluate the impacts of these new technologies.

- **Electric-drive vehicle sales tracking**: Collect monthly PEV, hybrid electric vehicle (HEV) and fuel-cell vehicle (FCEV) sales by make and model and summarize the market and technology trends
- **PEV national and regional impact assessment**: Quantify the national impact of PEV adoption on an annual basis
- **EV Lithium-ion battery supply chain tracking**: Summarize historical and future Li-Ion battery cell and pack production by manufacturer and by vehicle make/model
- **New mobility technologies tracking**: Summarize shared mobility data availability and trip trend by region and mobility type.
- **High fidelity PEV technologies characterization**: Seek insights into specific contributors to PEV efficiency (or lack thereof).
- **Sensors for highly automated vehicles**: Provide a comprehensive overview of current and emerging AV hardware, creating the foundation for a range of further technology development and energy impact assessment research.



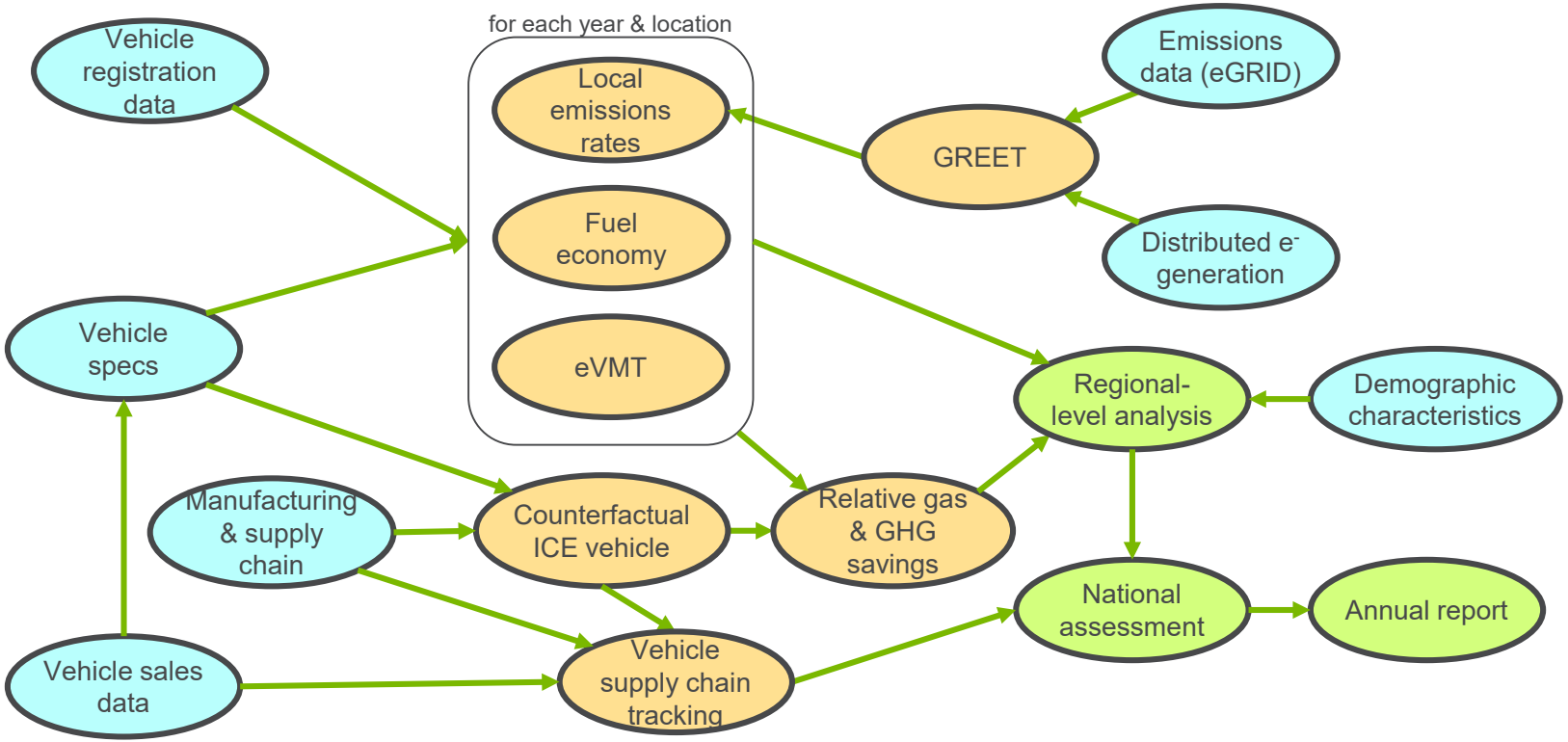
APPROACH

Data time-series back to 1999



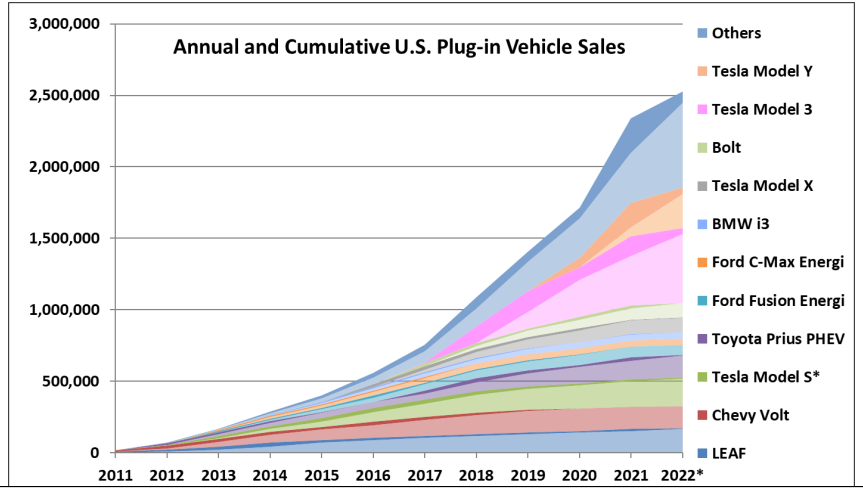
Topic	Method	Deliverables
• **E-drive and Mobility Technologies** • **Track E-drive projections** • **Track Battery Supply-chain** • **EV Efficiency Characterization**	• **Collect** sales, registration, efficiency data from databases, literature, testing etc. • **Analyze** how usage trends vary by demographic factors • **Summarize** market trends and technology evaluation • **Quantify** energy/emissions impacts at national and regional levels	• Monthly E-drive summary • Argonne webpage • Public facing reports • Selected results for Transportation Fact of the Week • Presentations to DOE

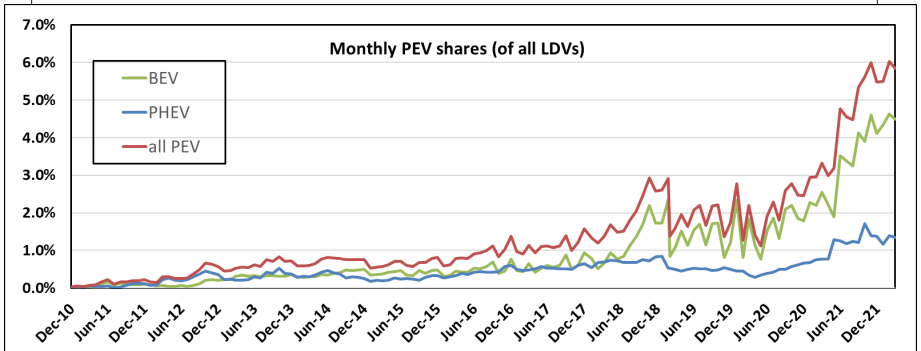
APPROACH: LOCAL GHG EMISSIONS EVALUATION



ACCOMPLISHMENTS: E-DRIVE VEHICLE SALES BY MAKE AND MODEL, AND MARKET TREND

Monthly summary report shared with DOE and public subscribers





Monthly E-drive Summary

- BEV, PHEV, FCEV, and HEV (Battery Electric Vehicle, Plug-in Hybrid Electric Vehicle, Fuel Cell Electric Vehicle, and Hybrid Electric Vehicle)
- Monthly and annual E-drive sales by make/model
- Cumulative sales
- Market shares
- Sales shares by OEM
- Sales shares by EPA size class
- Sales weighted efficiency and range
- Sales variation with gasoline price
- Comparison of sales since introduction (of top-selling models)

More contents can be found in our monthly reports, please contact yzhou@anl.gov for details

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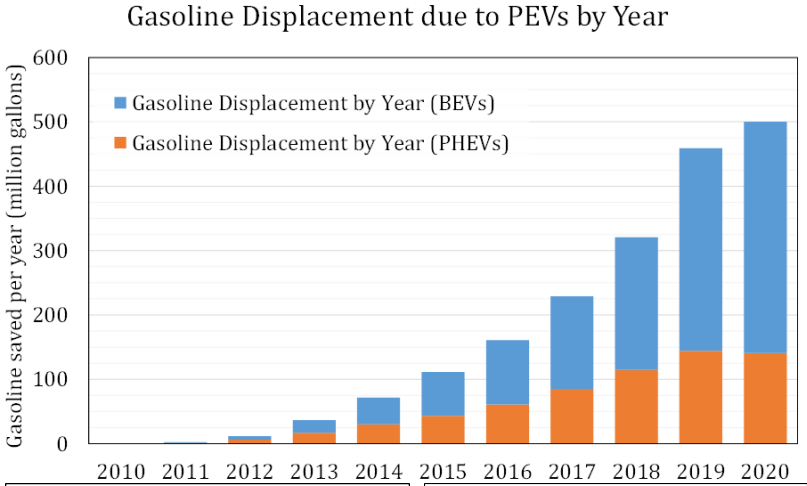
ACCOMPLISHMENTS: PEV TECHNOLOGY AND MARKET TRENDS AND RESULTING IMPACTS

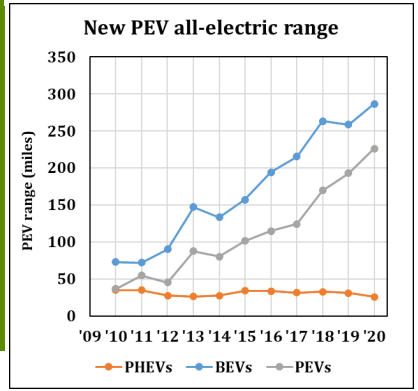
PEV Assessment Report
(Annually published)

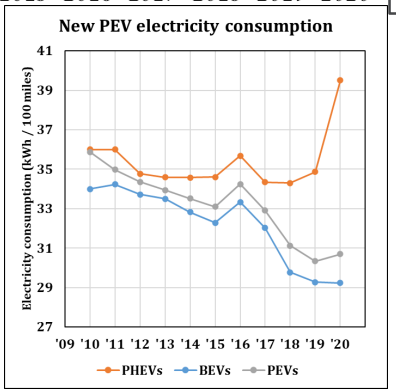
Aggregate Impact
- Electric miles traveled
- Gasoline replaced
- Carbon emission reduction
- Electricity consumption

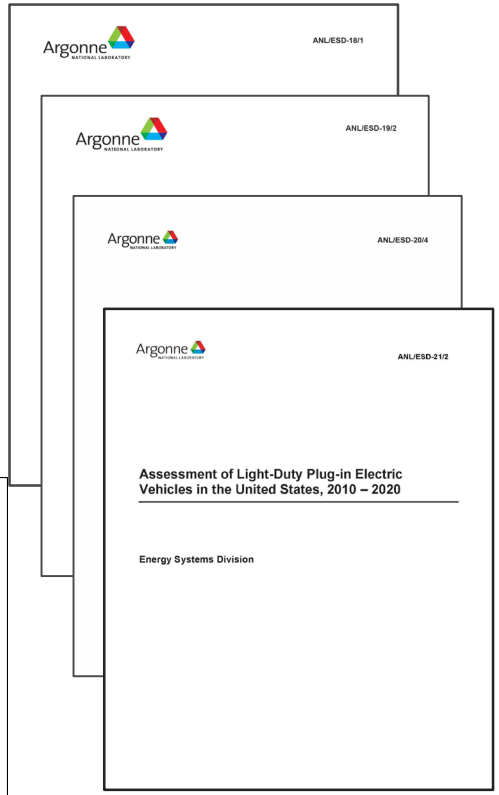
Vehicle Characteristics
- Electric range
- Electric efficiency
- Vehicle manufacturing and assembly
- Vehicle price
- Battery capacity and cathode chemistry

PEV = Plug-in Electric Vehicle









Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2020."Argonne National Laboratory, 2021, https://doi.org/10.2172/1785708

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ACCOMPLISHMENTS: SANKEY CHART OF GLOBAL Li-ION BATTERY SUPPLY CHAIN FOR U.S. PEV MARKET

From where to the US?

- The majority of PEVs sold in the U.S. have been assembled in the U.S., using battery packs built in the U.S.
- Majority of battery cells have come from U.S., Japan, and South Korea
- Other manufacturing locations include Germany and Belgium (vehicles & packs), Poland and Hungary (cells), and Mexico and Canada (vehicles)

Our report is cited in the NATIONAL BLUEPRINT FOR LITHIUM BATTERIES 2021–2030

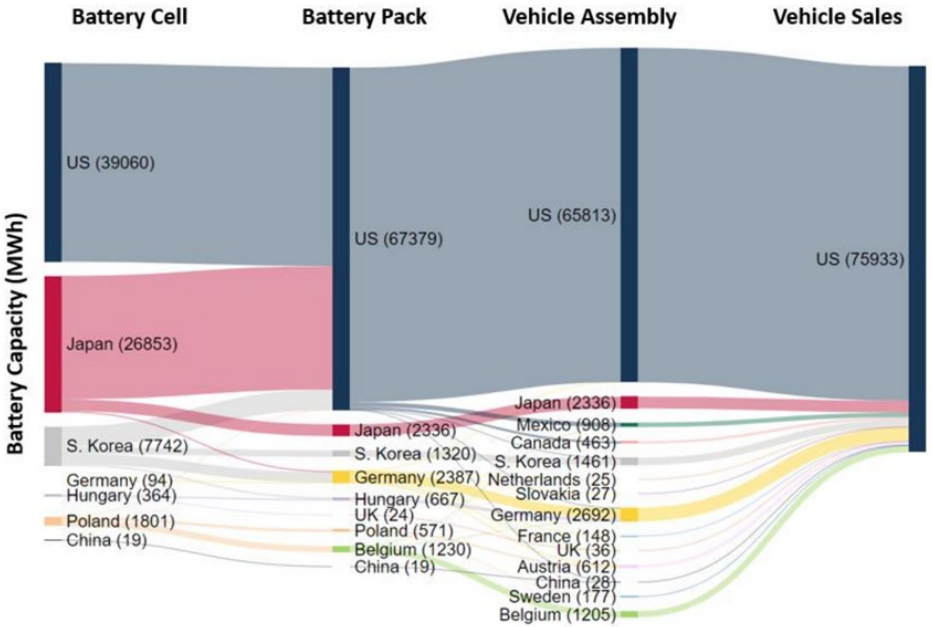

FIGURE ES-2 Total capacity (MWh) of Li-ion batteries supplied to the U.S. PEV market by production location, 2010–2020.

Zhou et. al, Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010–2020. United States: N. p., 2021. Web. doi:10.2172/1778934

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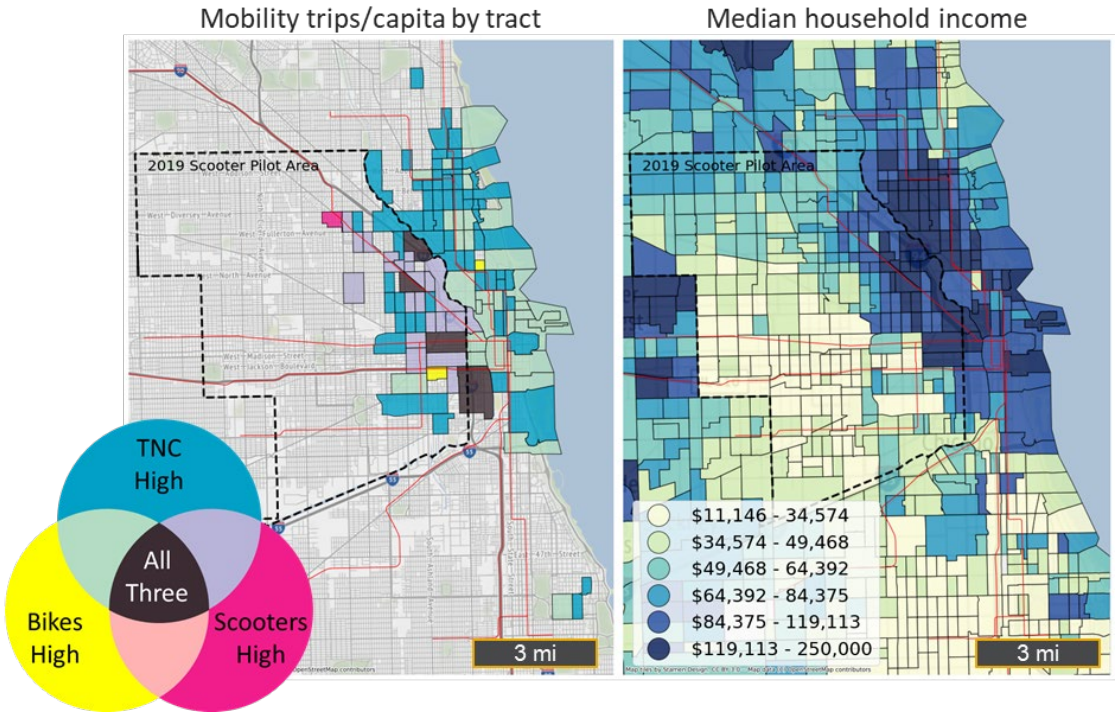
ACCOMPLISHMENTS: EVALUATED SHARED MOBILITY TECHNOLOGY USAGE IN CONTEXT OF HOUSEHOLD INCOME

- High shared mobility usage is centered in high income areas, despite good public transit accessibility
  - The left figure shows census tracts that are above the 90th percentile in trips per capita by scooters, bikes, TNCs, or some combination of the three
  - Tracts with high shared mobility usage are generally correlated across all three mobility types and are highly correlated with high income



Rush et. al, Shared Mobility Data Availability and Usage Trends. Argonne National Laboratory report ANL/ESD-22/9, May 2022.

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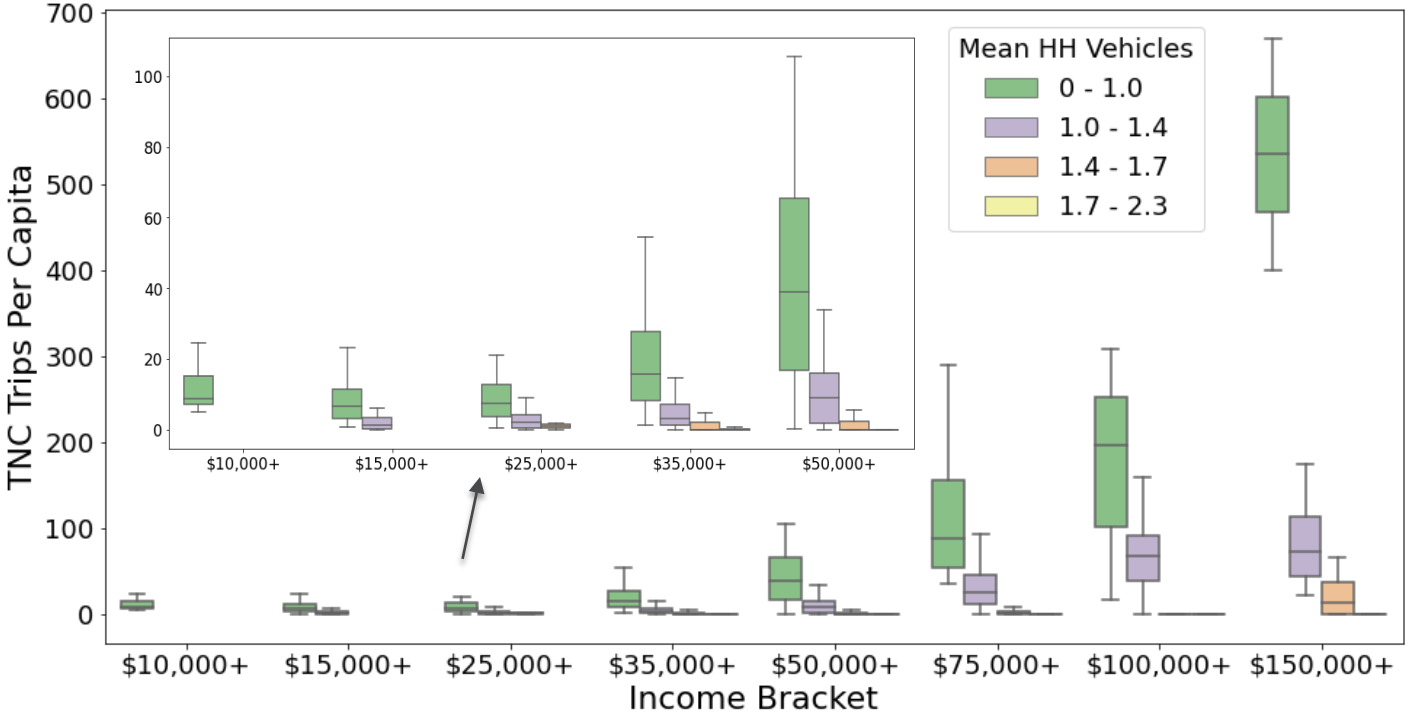
ACCOMPLISHMENTS: ANALYZED HOW SHARED MOBILITY USAGE VARIES BY HOUSEHOLD INCOME AND THE NUMBER OF VEHICLES PER HOUSEHOLD

- Tracts with higher household income and fewer household vehicles tend to have higher Transportation Network Company (TNC) usage per capita
- Similar trends are observed for bikeshare and scooter share

TNC trips per capita by income and # of household (HH) vehicles



Rush et. al, Shared Mobility Data Availability and Usage Trends. Argonne National Laboratory report ANL/ESD-22/9, May 2022.

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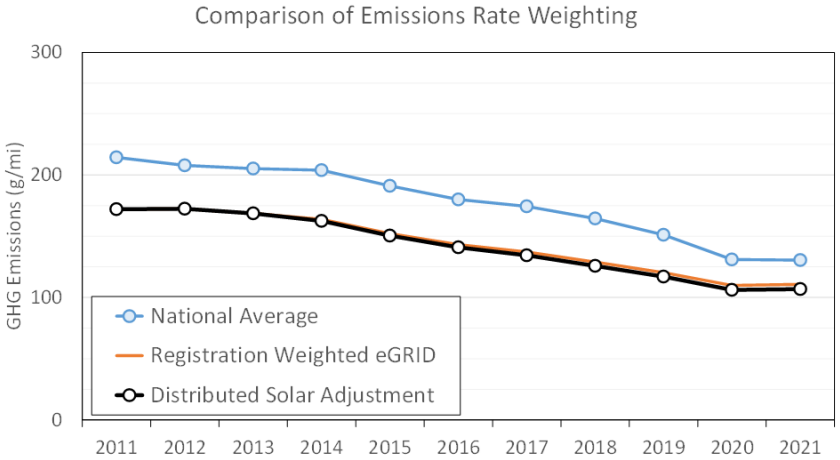
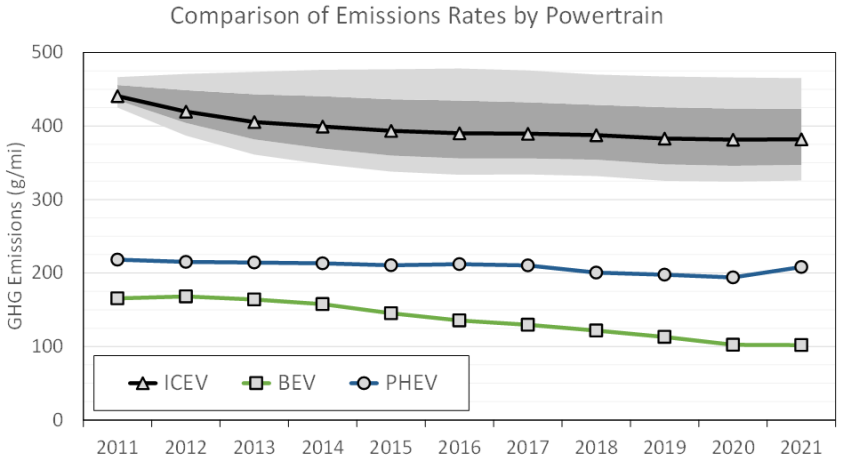
ACCOMPLISHMENTS: HISTORICAL ASSESSMENT OF THE GHG EMISSIONS OF ELECTRIC VEHICLES IN THE UNITED STATES, FROM 2010 TO 2021

- Weighted-average WTW emissions show a downward trend
- Growth of residential distributed solar PV in the US has demonstrated an increasing impact on grid



- PEVs have reduced US WTW emissions by 15-27 million metric tons from 2011 to 2021
- Actual reductions depend on characteristics of Internal Combustion Engine Vehicles (ICEV) that have been replaced



Regionally-Resolved Emissions from Electric Vehicles in the United States, Argonne National Laboratory Technical Report (2022)

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RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

- Worth spending some time with a data visualization expert to improve most of the charts that are being published… it is very important for researchers and the public to have access to accurate and well-maintained open vehicle sales databases…

Agree. We propose to improve the data visualization (e.g., a dashboard) for data published on the Argonne website to better translate raw data into insights.

- One other potentially interesting area is how trends are varying by region or nation

Agree. We now subscribe to Experian Automotive Data, so we have examined the regional variation and its impacts on GHG emissions and energy consumption.

- Further expanding work to include MD and HD commercial vehicles

Agree. With the growing electric MD and HD markets, we will continue to explore reliable data sources.

- The team may need to develop additional collaborative efforts to collect and analyze a variety of new mobility data

We have interacted with several local agencies that collect mobility usage data, presenting our results and collecting suggestions.

COLLABORATION AND PROPOSED RESEARCH

Collaboration

- ORNL provides monthly vehicle sales from Wards' Auto
- Interact with regional agencies collecting mobility usage data
- Discuss the research insights with Clean Cities and City of Chicago

Proposed Research *(Note: Any proposed future work is subject to funding levels)*

- Continue the effort **collecting available data** and **improving data visualization**
- Quantify **national impacts, track supply chain** and publish **public-facing documents**
  - Quantify energy and emissions impacts
  - Document technology evolution trends
  - Track battery and vehicle supply chain
  - Annually update the reports
- Assess how **technology adoption and usage** evolves and varies by demographic factors
- Quantify **regional impacts** of electrification: a state-by-state comparison
  - Difference in PEV models adopted at regional level
  - Energy and emissions impacts due to regional differences

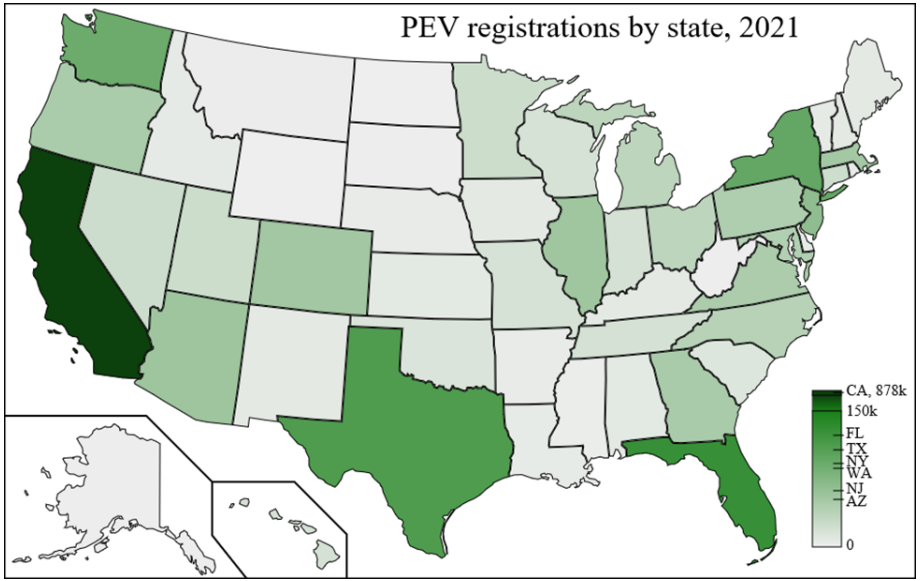
SUMMARY

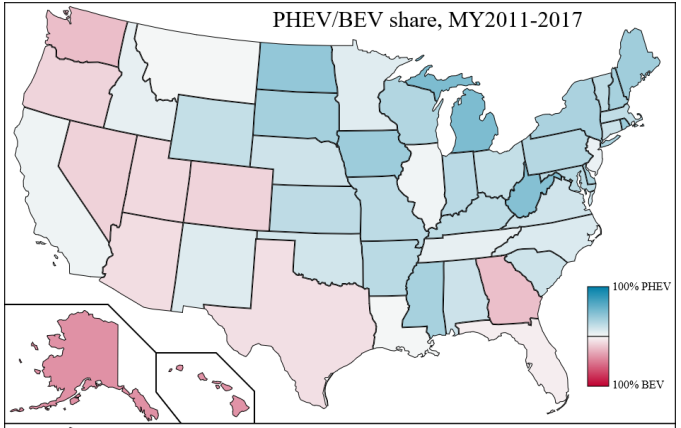
- **Objectives:** Synthesize and improve upon data for electrification and mobility technologies to evaluate the impacts of these new technologies
- **Outcomes:** To better inform VTO analysis, analysis-supported activities, associated stakeholders and general public
- **Methods:** Collect data from different databases, literature, and testing results, and summarize the market and technology trends
- **Results:** Documented in Excel files and in public-facing documents for DOE and general subscribers to these monthly and yearly reports
- **Other Publications:** Selected data are published on the Argonne website, and as part of DOE/VTO's Transportation Fact of the Week
- **Milestones:** Successful monthly, quarterly, and annual milestones delivered on-time and within budget – improving over time as more data becomes available

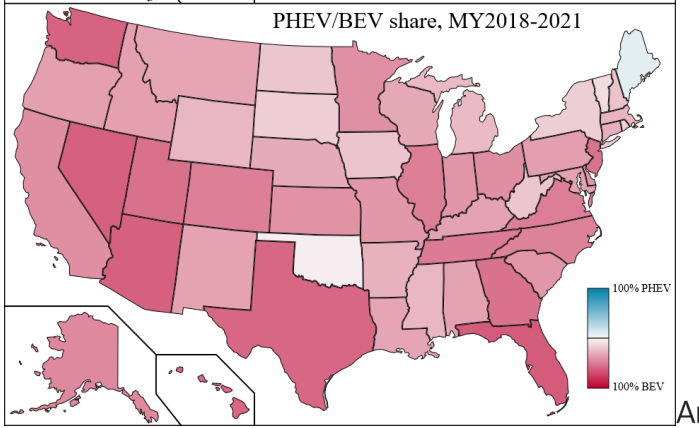
TECHNICAL BACKUP SLIDES

ACCOMPLISHMENT: DISTRIBUTION OF ELECTRIC VEHICLES REGISTERED IN THE UNITED STATES

- California is by far the state with the most registrations
- A rapid shift in the PEV market toward all-electric vehicles over the last few years







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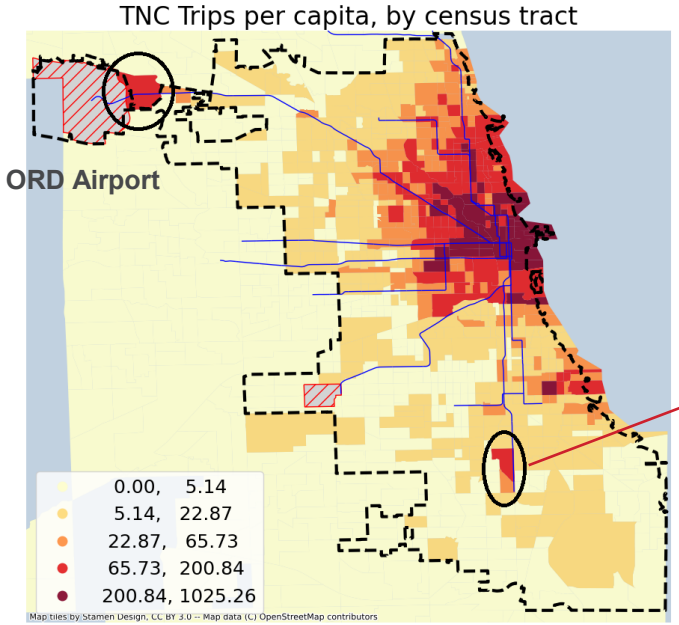
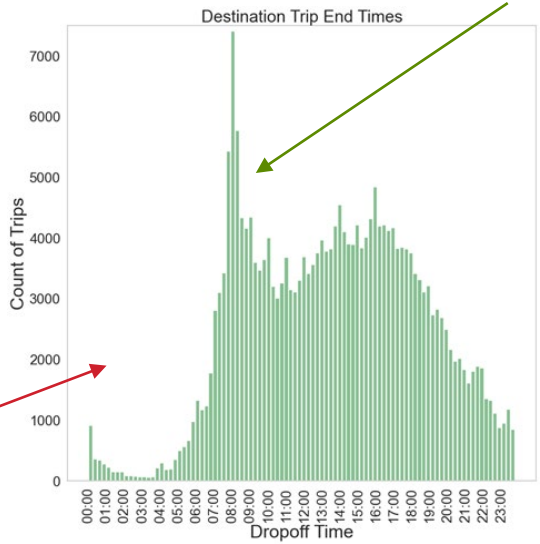
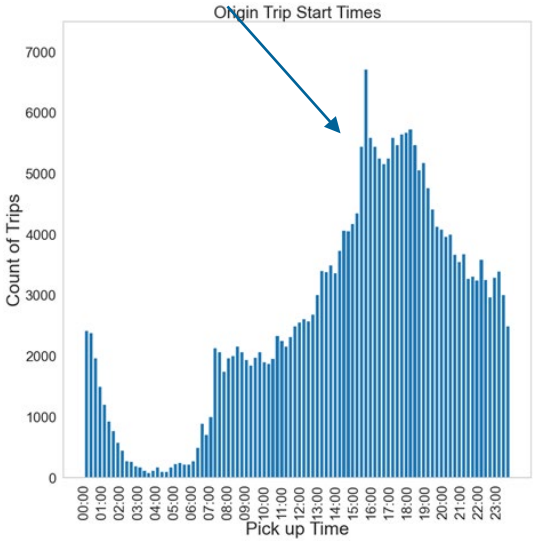
ACCOMPLISHMENTS: TNC IS USED FOR FIRST-MILE AND LAST MILE IN LOWER INCOME COMMUNITIES

- TNC ridership peaks near ends of train lines



- Increase in **arrivals** & **departures** corresponding to morning/evening rush





- Shorter average TNC distance in vicinity of transit stops: multi-modal, last-mile use of TNC by local residents

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ACCOMPLISHMENTS: SANKEY CHART OF GLOBAL LI-ION BATTERY SUPPLY CHAIN FOR U.S. PEV MARKET

Who is supplying batteries to whom?

- Panasonic is the largest supplier of battery cells, largely for use in Tesla vehicles, but also supplies packs to other OEMs
- LG Chem has supplied batteries for several different automakers
- AESC has supplied batteries for the Nissan Leaf

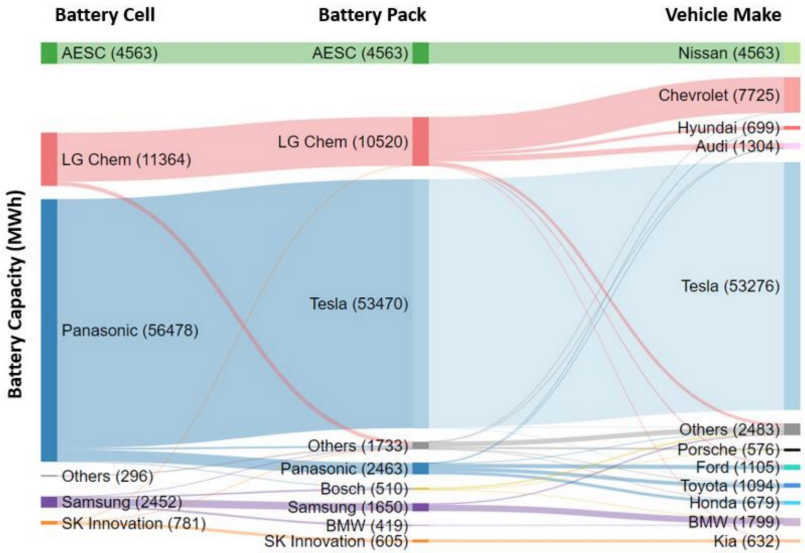
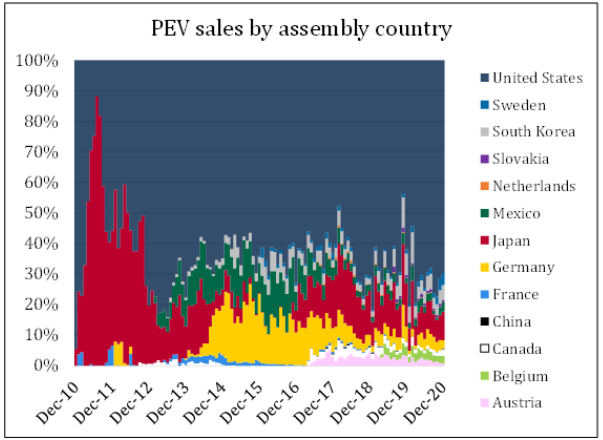


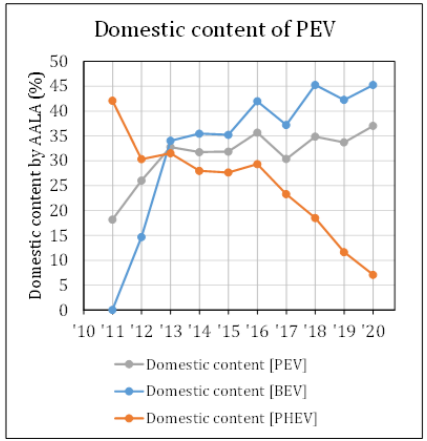
FIGURE 2-7 Total capacity (MWh) of Li-ion batteries supplied to the U.S. PEV market by manufacturer, 2010–2020. "Others" for battery cells includes Li-tec, GS Yuasa, Toshiba, Blue Energy, and A123. "Others" for battery packs includes Accumotive, GS Yuasa, Primearth EV Energy, Toshiba, Blue Energy, A123, Jaguar, and Draexlmaier. "Others" for vehicle makes includes Smart, Mitsubishi, Fiat, Cadillac, Mercedes, Volkswagen, Volvo, Hyundai, Chrysler, MINI, Jaguar, Subaru, Land Rover, Lincoln, Polestar, and Jeep.

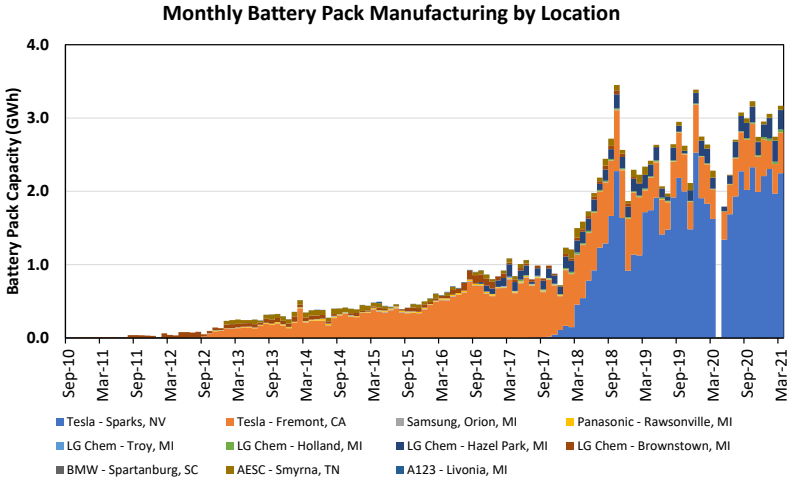
Source: Zhou et. al, 2021; https://www.osti.gov/biblio/1778934

ACCOMPLISHMENTS: TRACK E-DRIVE VEHICLE AND BATTERY MANUFACTURING BY LOCATION

- While most BEVs sold in the U.S. have been made here since 2013, more PHEVs are being assembled abroad
- Majority of battery packs in the U.S. are assembled in either Fremont, CA or Sparks, NV (Tesla Gigafactory)







Gohlke and Zhou, 2021; https://www.osti.gov/biblio/1785708

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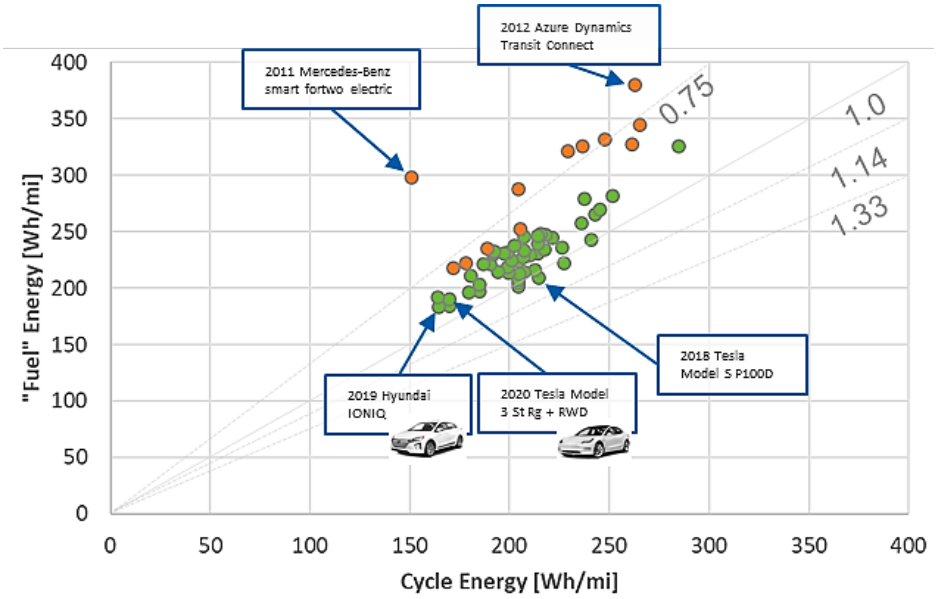
ACCOMPLISHMENTS: ELECTRIFICATION EFFICIENCY INSIGHTS FOR VTO

Analysis of MY 2012-2020

- Wheel energy vs consumed energy
- City vs Highway Efficiency
- Coefficient of Rolling Resistance vs Aerodynamic forces
- Tracking model changes over time
  - Range vs Battery vs Efficiency

Conclusions

- Extra battery weight increases wheel energy
- Powertrain efficiency suffered in those models that only increased battery size *(e.g., i3, not shown in graph)*
- Most models increased range improving BOTH efficiency and battery size
- Tesla included many improvements, but most interestingly, switch to AWD
  - Adding PM motor for main drive vs AC ind



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