

NARUC Electric Vehicles State Working Group

FORECASTING DISTRIBUTION UPGRADE NEEDS UNDER UNCERTAINTY

JUNE 25, 2024, 3:00 - 4:30 PM ET

Welcome

EV SWG Chair

Commissioner Katherine Peretick, Michigan Public Service Commission

EV SWG Vice Chair

**Commissioner Milt Doumit, Washington Utilities and Transportation
Commission**

EV Commission Staff Leads

Ryan Cheney, North Carolina Utilities Commission

Steve Olea, Arizona Corporate Commission

NARUC Staff

Danielle Sass Byrnett and Robert Bennett

Agenda

Feel free to enter
questions into chat at
any time

3

3:00 PM	Welcome and Announcements: Commissioner Doumit <ul style="list-style-type: none">• Agenda review• Summer Policy Summit
3:10 PM	Paige Jadun, National Renewable Energy Laboratory (NREL)
3:25 PM	Sean Morash, Telos Energy
3:40 PM	Sanem Sergici, the Brattle Group
3:55 PM	Speaker Q&A
4:15 PM	Peer Sharing Discussion
4:30 PM	Adjourn

EV Fact of the Week:

Battery Cell Production in North America is Expected to Exceed 1,200 GWh per Year by 2030, Providing Enough Cells for at Least 12 Million New EVs annually

For more info and other facts, visit [DOE FOTW](#) webpage.

Summer Policy Summit

- ▶ 2024 Summer Policy Summit, July 14-17, West Palm Beach, Florida
 - ▶ Register here: <https://www.naruc.org/summer-summit-2024/>
 - ▶ ERE Panel on **preparing the Grid to meet the EV transition, Monday, July 15, 2:00- 3:00 pm ET**

Presentations on Forecasting Distribution Upgrade Needs under Uncertainty

Moderator: Commissioner Milt Doumit, Washington Utilities and Transportation Commission

Guest Speaker

- **Paige Jadun, National Renewable Energy Laboratory (NREL)**
 - EV load forecasting uncertainty study
- **Sean Morash, Telos Energy**
 - *ESIG Charging Ahead: Grid Planning for Vehicle Electrification, load forecasting*
- **Sanem Sergici, the Brattle Group**
 - ERCOTT EV Allocation Study



Exploring Uncertainty in Electric Vehicle Load Forecasting

Paige Jadun

Based on work with Bo Liu, Arthur Yip, Adway Das, and Matteo Muratori

NARUC EV State Working Group

June 25, 2024

The transportation landscape is changing rapidly

Electrified transportation overtook renewables, with \$634 billion invested globally in 2023 – 36% increase from 2022. – [BloombergNEF](#)

U.S. EPA proposed rules to ensure that **two-thirds of new cars** and a **quarter of new heavy trucks** sold in the United States by **2032** are all-electric.

– [New York Times \(2023\)](#)

California **bans new combustion engine** cars starting in 2035.

– [Cal Matters \(2022\)](#)

Sales of electric cars topped 14 million globally in 2023 – **18% of sales** (almost 1 vehicle in 5 sold was an EV). – [International Energy Agency \(2024\)](#)

Battery costs have declined 90% since 2010 with pack prices expected to be \$100/kWh by 2026. – [BloombergNEF \(2022\)](#)

Renewables account for 99% of U.S. electricity capacity installed in 2024. – [Clean Technica based on FERC data \(2024\)](#)

Amazon places an order for **100,000 electric delivery vans**, with thousands on the road today.

– [Business Insider \(2022\)](#)

Six major automakers to **phase out new gas vehicles** by 2035 in leading markets.

– [Car and Driver \(2021\)](#)

Tesla delivers first **500-mile range electric semi trucks** to PepsiCo. – [CNN \(2022\)](#)

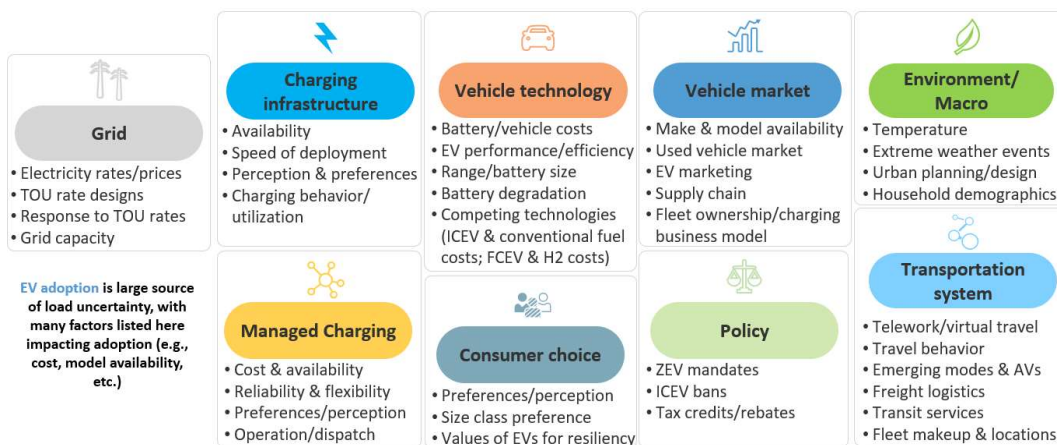
...but what will be the impact on future EV load?

While transport electrification is expected, load impacts are highly uncertain

High degree of uncertainty exists in **how much, where, and when** EV load will occur depending on many factors

National-level or average assumptions will miss **local impacts** (regional and temporal) of particular concern to planners

Example factors of uncertainty



Yip et al. Forthcoming



Savage, Sam L. The flaw of averages: why we underestimate risk in the face of uncertainty. John Wiley & Sons, Inc., 2012

Understanding sources of load uncertainty and considering for local factors can help create more robust forecasts

Multiple dimensions determine total EV load

- **Adoption & ownership:** how many vehicles and of what kind?
- **Vehicle use/travel behavior:** how many miles travelled?
- **Energy consumption/intensity:** how much energy is consumed per unit of travel?
- **Charging behavior & technology:** when, where, and how will EVs charge?

All subject to **inherent heterogeneity** (*i.e.*, regional and temporal variations) and **forecast uncertainty** (*i.e.*, uncertainty of the future)

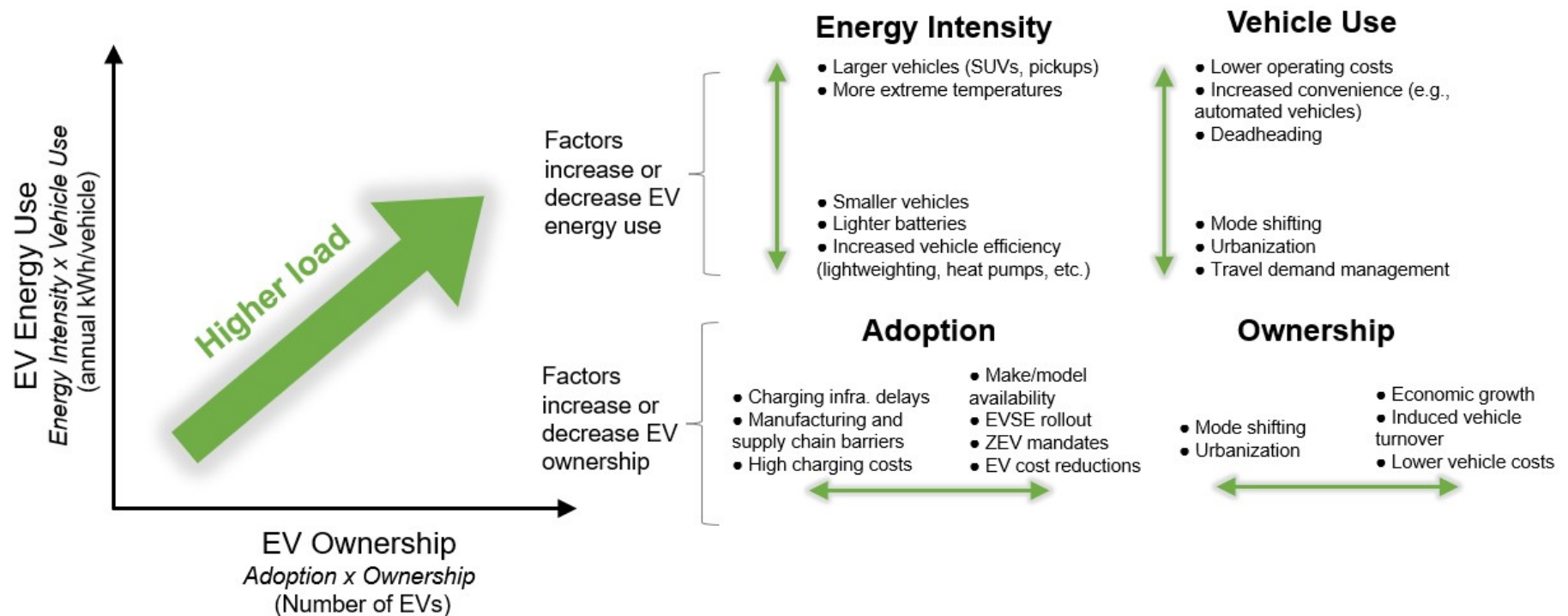


How much load, when, and where?

Changes along any dimension can impact how much total EV load

Load is determined by EV energy use and EV ownership

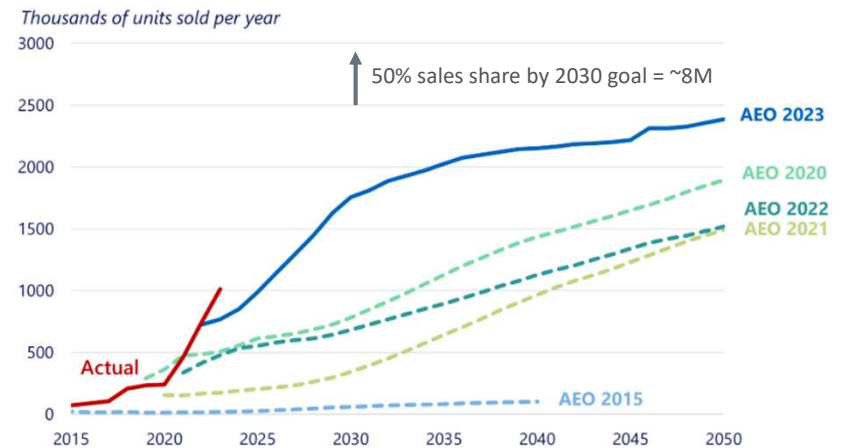
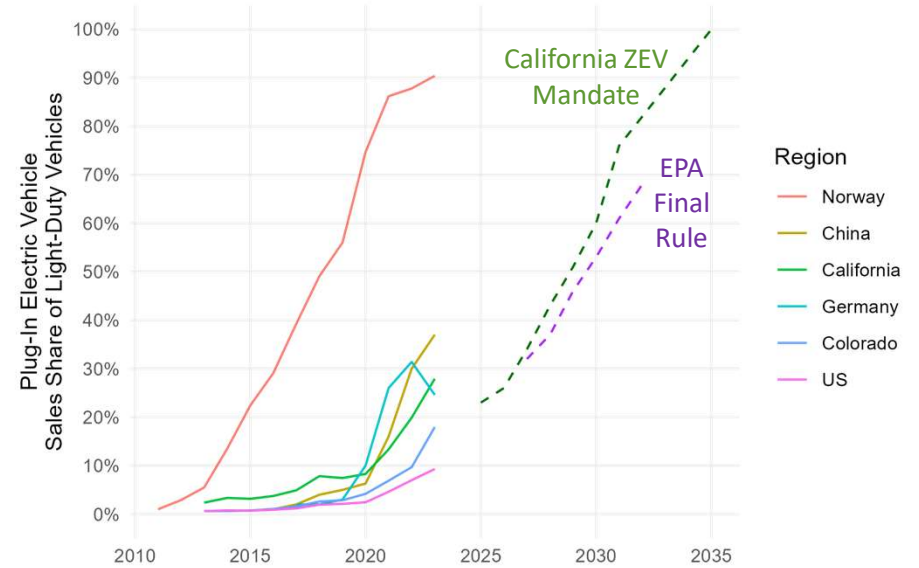
Various factors of uncertainty impact each dimension of load



Where and when EV load will occur further determined by regional characteristics....

EV Adoption

- Recent data point to rapid growth in EV adoption
- Many historic projections have underestimated rate of growth (predicting adoption is difficult!)
- Even assuming adoption goals will be met (e.g., 50% by 2030), **uncertainty remains in other dimensions**



Sources: U.S. Energy Information Administration, Argonne National Laboratory.
 Note: Projections from EIA Annual Energy Outlook. Actuals from ANL Light Duty Electric Drive Sales Monthly Sales Updates.
 As of December 14, 2023.

EV adoption varies by region

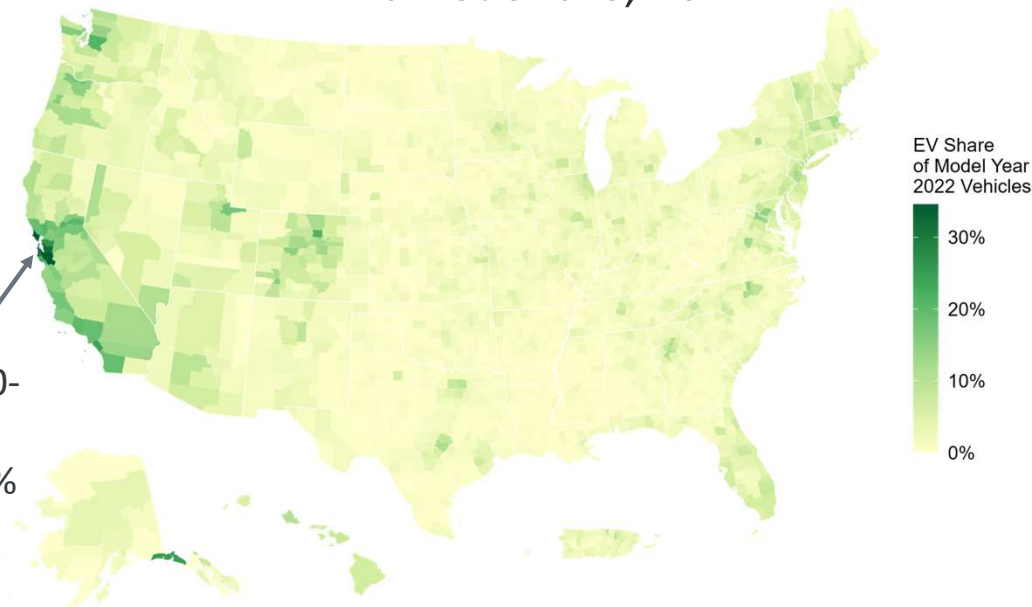
“The future is already here; it’s just not very evenly distributed.”

– William Gibson

Some counties exceeded 20-30% sales share in 2022, while others are close to 0% (vs. 7% nationally)

Understanding local EV market maturity compared to national average estimates can help inform near-term adoption assumptions; applicability to longer-term estimates should be considered

EV Market Share, 2022



Note: EV includes BEV and PHEV.
Source: NREL analysis of 2022 Experian vehicle registration data,

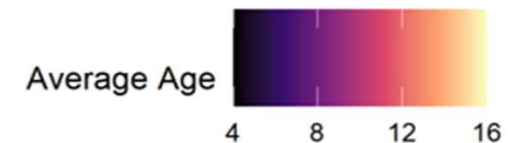
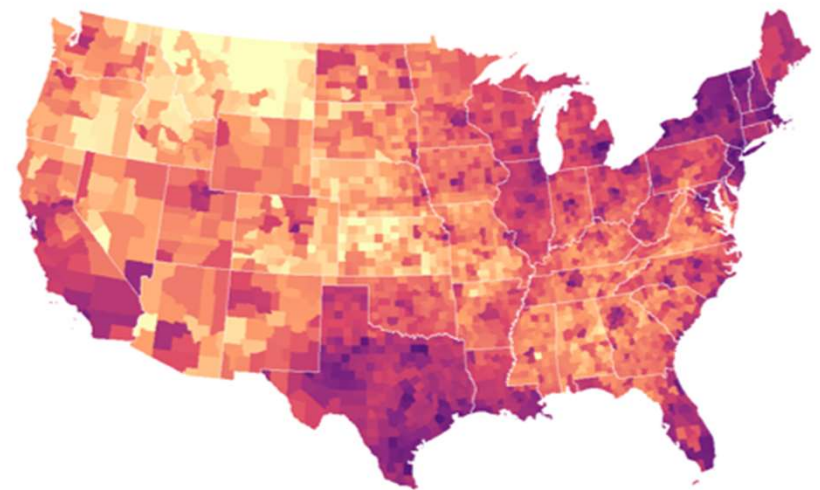
Source: [Yip et al. \(2023\) Highly Resolved Projections of Passenger Electric Vehicle Charging Loads for the Contiguous United States](#)

Vehicle Ownership

- Vehicle sales do not equal vehicle stock
- Regional vehicle ownership trends may dictate how fast electrification will happen
 - Regions with slower stock turnover may take longer to electrify
- Used vehicle markets will also impact diffusion (EV dynamics still uncertain)

Considering local characteristics of total vehicle sales and vehicle age can improve accuracy of vehicle stock projections

Average Age of Household Vehicles



Vehicle use and travel behavior

- **Vehicle miles traveled (VMT) varies by geography**, impacted by population density, access to public transit, vehicle ownership, etc.
- Total VMT is generally expected to increase with population and economic growth, but may be impacted in the mid- to long-term by
 - **New technologies and business models** (e.g., autonomous vehicles, ride-hailing)
 - **Decarbonization strategies** aimed at reducing VMT (e.g., public transit, urban planning)

Strategies to improve mobility convenience and efficiency can impact VMT, but likely on a longer timescale

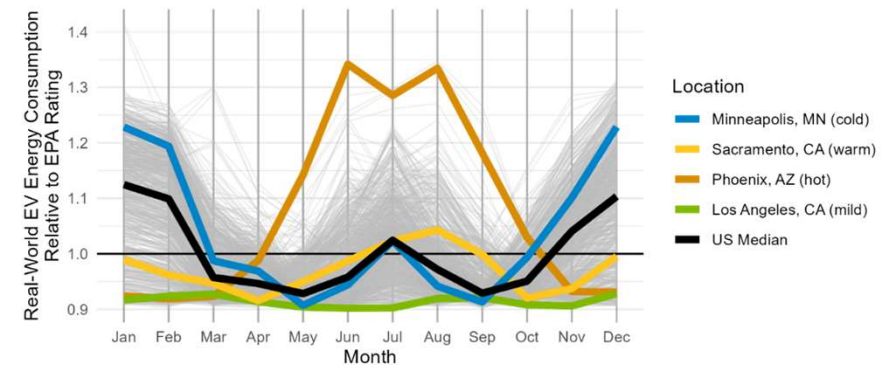
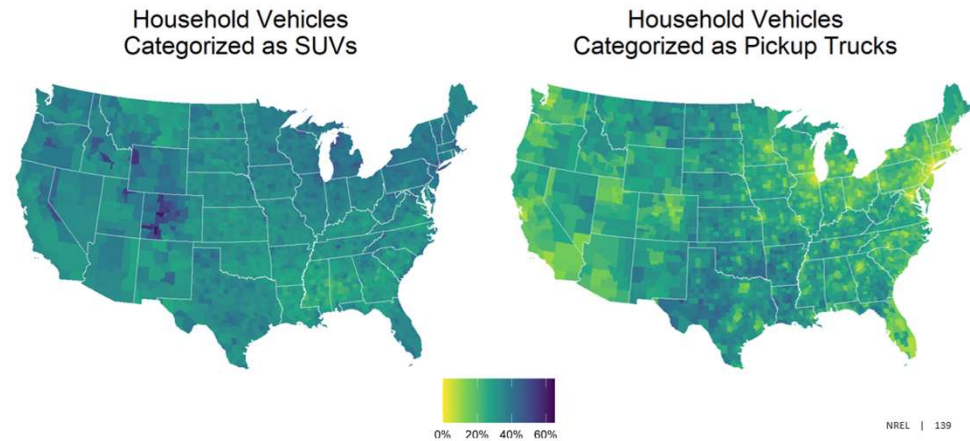


Regional VMT characteristics should be considered; sensitivity analysis of VMT informed by transportation studies can help capture uncertainty in longer term load scenarios

Energy intensity

- Energy intensity is impacted by regional factors including
 - Vehicle size
 - Temperature
 - Road grade
 - Drive style
 - Etc.
- Vehicle efficiency advancements achieved through vehicle R&D can also play a large role

Local data on vehicle characteristics/operations and temperature can refine energy intensity estimates; future vehicle technology assumptions should be informed by robust sources



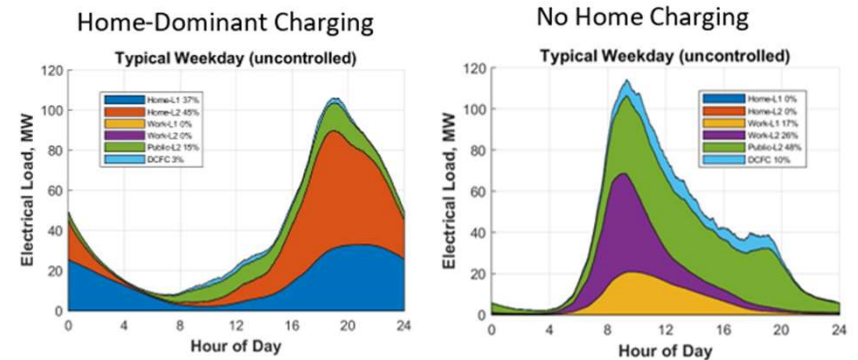
Source for both figures: [Yip et al. \(2023\) Highly Resolved Projections of Passenger Electric Vehicle Charging Loads for the Contiguous United States](#)

Charging behavior and technology

- EV load shape is impacted by
 - Charging infrastructure availability (and dependence on building stock types)
 - Charging power/technology
 - Charging preferences and behavior
- Current trends may not reflect future conditions (location and power levels)

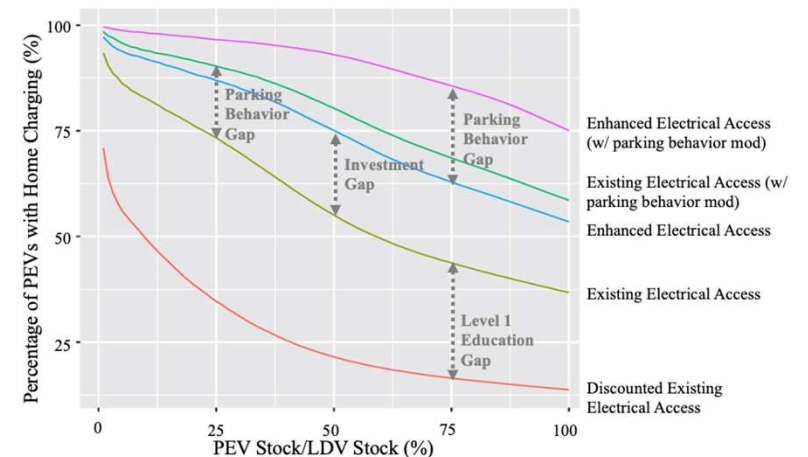
Consideration of potential for evolving load profiles can inform more robust forecasts/sensitivities

Load shapes differ by charging preference, power level



NREL EVI-Pro Model: <https://www.nrel.gov/transportation/evi-pro.html>

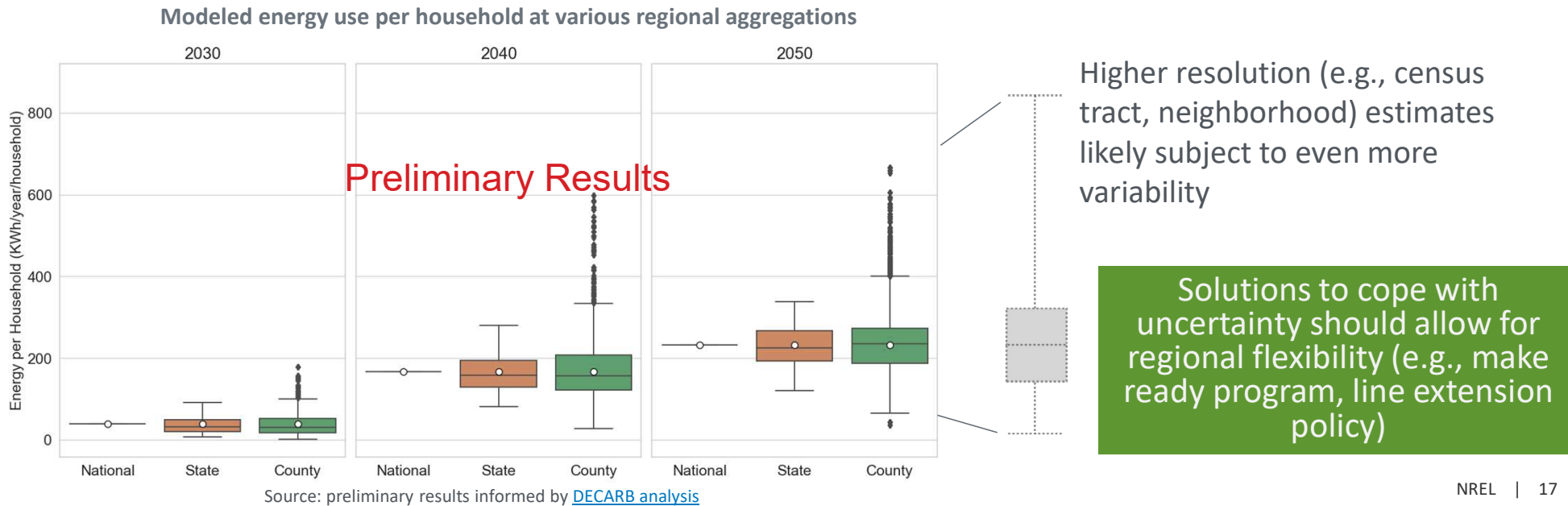
Charging access will vary with higher EV penetrations



[Ge et al. 2021.](#)

Regional and Temporal Uncertainty

- Projecting load at a high level of resolution is hard!
- Extreme uncertainty is expected in how individual households, businesses, and fleets will electrify and how they will charge



Characteristics of a good EV load forecast

- Considers **all dimensions impacting load** (touching on multiple disciplines and subjects of expertise)
 - Multidisciplinary collaborations and transparent data/analysis can help inform all stakeholders
- Uses **localized data** where applicable, including:
 - Local EV market maturity
 - Policy and sociodemographics affecting EV adoption propensity
 - Overall vehicle sales, ownership, and use by market segment
 - e.g., vehicle turnover, vehicle size class composition, VMT, MHDV fleets composition and operations
 - Weather-based energy impact
 - Charging availability (including building stock types and public charging)
- Employs **cautious treatment of extrapolating recent trends** and/or inherent heterogeneity to future scenarios
- Includes **uncertainty** in key assumptions

Thank you!

Paige.Jadun@nrel.gov

www.nrel.gov

References and Sources

- Ge, Yanbo, Christina Simeone, Andrew Duvall, and Eric Wood. 2021. “There’s No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure.” NREL/TP-5400-81065. National Renewable Energy Lab. (NREL), Golden, CO (United States). <https://doi.org/10.2172/1825510>.
- NREL (National Renewable Energy Laboratory). 2023. 2022 Transportation Annual Technology Baseline. Golden, CO: National Renewable Energy Laboratory. <https://atb.nrel.gov>.
- NREL. Electric Vehicle Infrastructure Projection Tool (EVI-Pro). <https://www.nrel.gov/transportation/evi-pro.html>
- NREL. Transportation Energy and Mobility Pathway Options Model (TEMPO). <https://www.nrel.gov/transportation/tempo-model.html>
- Yip, A., Jadun, P., Liu, B., Mazzone, D., & Matteo Muratori. Forthcoming. *Exploring Uncertainty in Electric Vehicle Load Forecasting*. National Renewable Energy Laboratory.
- Yip, Arthur, Christopher Hoehne, Paige Jadun, Catherine Ledna, Elaine Hale, and Matteo Muratori. 2023. “Highly Resolved Projections of Passenger Electric Vehicle Charging Loads for the Contiguous United States: Results From and Methods Behind Bottom-Up Simulations of County-Specific Household Electric Vehicle Charging Load (Hourly 8760) Profiles Projected Through 2050 for Differentiated Household and Vehicle Types.” NREL/TP-5400-83916. National Renewable Energy Laboratory (NREL), Golden, CO (United States). <https://doi.org/10.2172/1984452>.

Charging Ahead: Grid Planning for Vehicle Electrification

A Whitepaper from the ESIG Grid Planning for Vehicle Electrification Task Force

June 2024



Presentation by
Sean Morash, Telos Energy

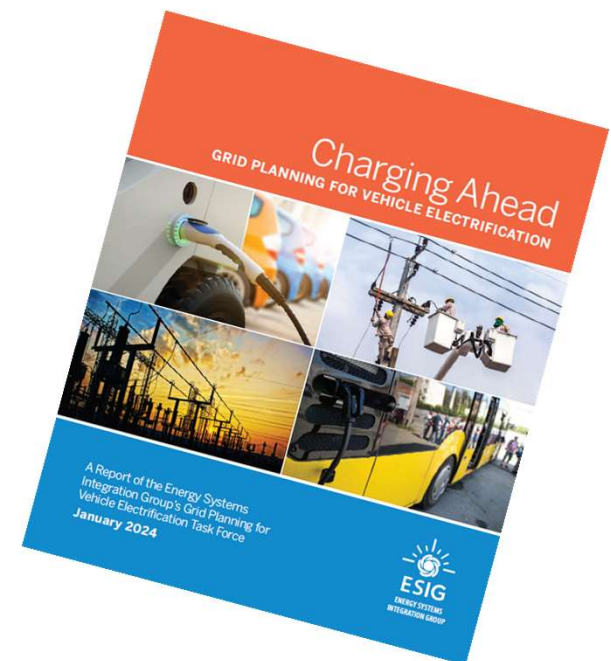
Acknowledgements



Many Thanks To:

- DOE
- LBNL
- ESIG DER WG
- Task Force Members
 - Utilities
 - Vehicle Manufacturers
 - Aggregators
 - Charging Operators
 - Regulators
 - State Energy Offices

The work described in this webinar was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.



<https://www.esig.energy/grid-planning-for-vehicle-electrification/>

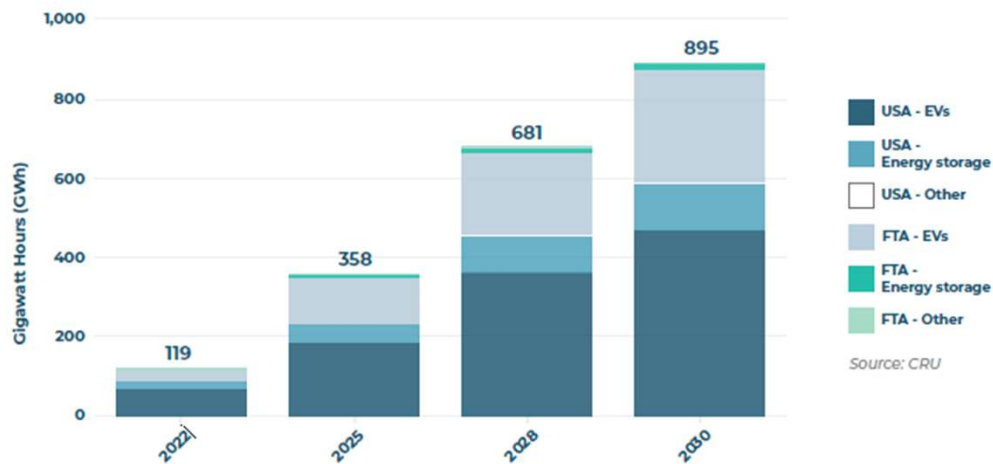
How big of a change is this?

25 GWh

126 GWh

Stationary Battery Storage in the US today²

Storage in the 2.1M EVs on the road today²



Source: CRU

Nearly unprecedented change:

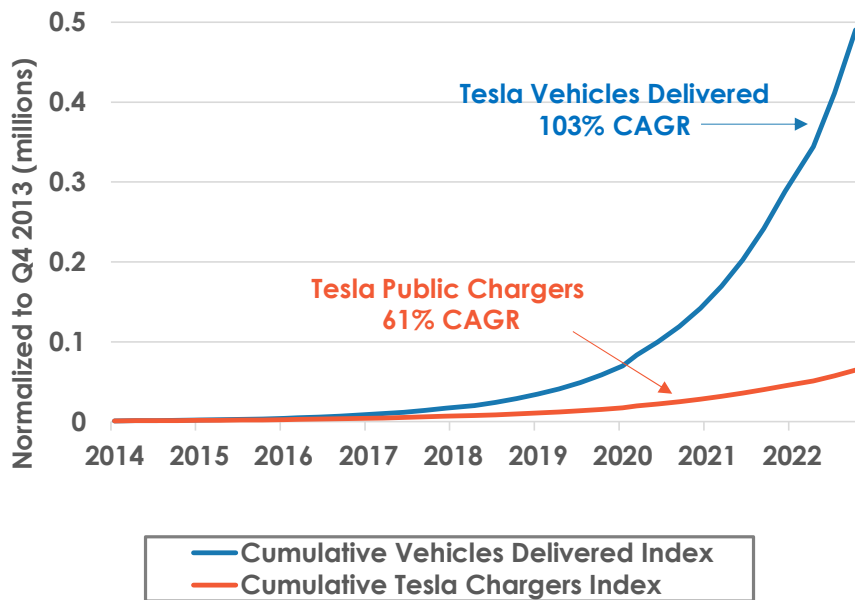
- EVs are first major load growth since air conditioning in the 1960s.
- Demand from 1 EV ≈ 1 house
- Concentration of EVs can overwhelm local distribution system capacity.
- Adoption rates to vary significantly across communities
- Cumulative distribution investment across the country could be \$200B by 2050 to facilitate EVs.¹

Transportation electrification continues to accelerate

Drivers: customer demand, commitments from vehicle manufacturers, public policy targets and incentives

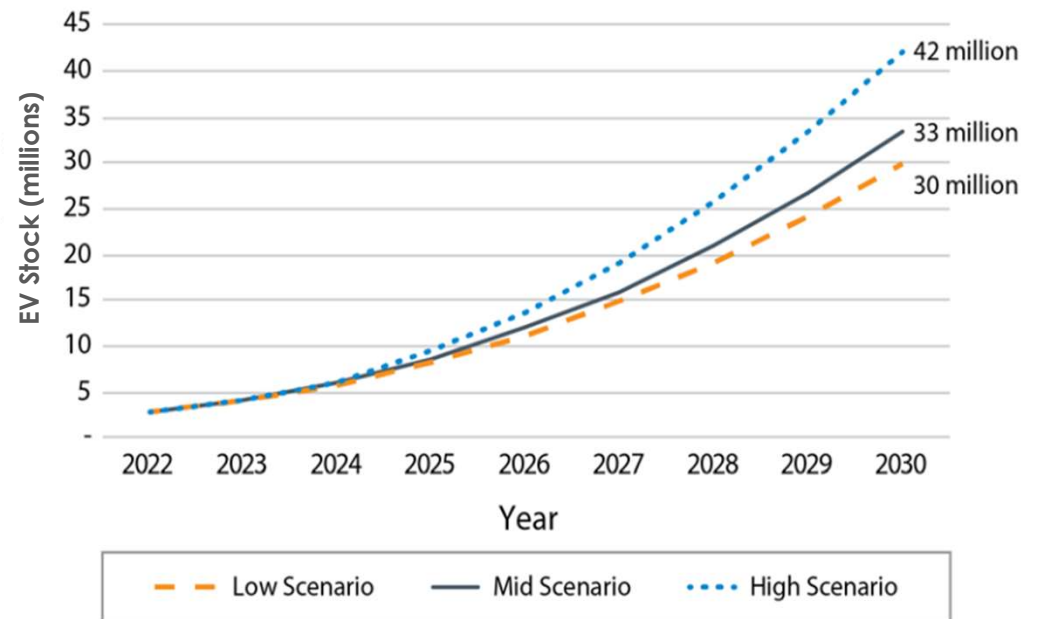


Tesla vehicles delivered and public chargers¹



U.S: EV Adoption Scenarios (light-duty)²

33million EVs = 1200+ GWh



The pace of EVs on the road has far exceeded public charging network roll-out for a variety of reasons, including a lack of sufficient grid infrastructure. This trend is also seen in non-Tesla charger deployments and highlights the accelerating demands of grid planning to support vehicle electrification.

¹Tesla Comments to the California Energy Commission, 9/1/2023. ²NREL. 2023. *The 2030 National Charging Network*

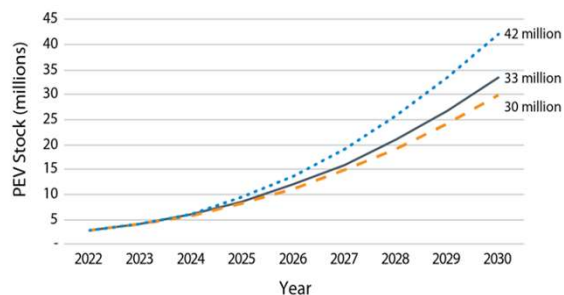
Uncertainty Abounds



Adoption Rates?

How many vehicles are expected by when?

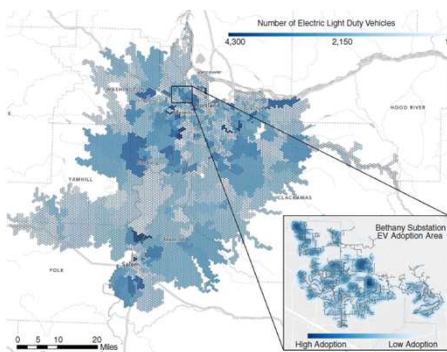
- Type of vehicles (SUV, trucks)
- Technology Change (efficiency & battery technology)
- Use Cases (LDV, MDV, fleets)



Location of Charging?

Where will charging take place?

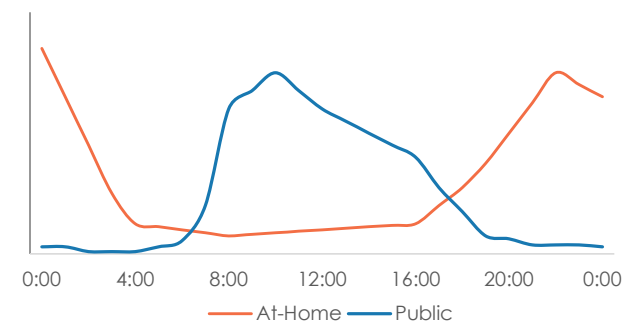
- Home vs. workplace charging?
- Which communities will see adoption first?
- Where do people drive?



Timing of Charging?

When will vehicle owners charge?

- Hourly charging profiles
- Event-based planning (holidays, storms, etc.)
- Rate design and incentives



The answer to each of these questions has significant implications for power system planning and cost, particularly for distribution networks.

Prioritizing Grid Planning Actions to Take Today



Priorities for effectively integrating vehicle electrification into grid planning

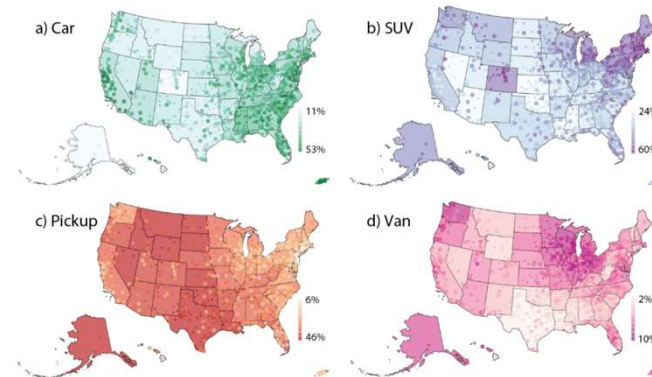


1. **Improve forecasting** by considering multiple vehicle end uses, new vehicle technologies, and more data sources. Use of scenarios to capture the uncertainty of locational and temporal grid impacts .
2. **Embrace smart charging** options at every level of the grid from the premise to the bulk system. Targeted smart charging, operating limits, and strategically located storage can help bridge immediate load growth while long-term solutions are implemented.
3. **Incorporate future-ready equipment** to allow for upsizing of infrastructure or enable future upsizing whenever equipment is being replaced.
4. **Promote proactive upgrades** identified by a multi-stakeholder group because EV adoption and charging needs can grow much faster than utility upgrades can be implemented.

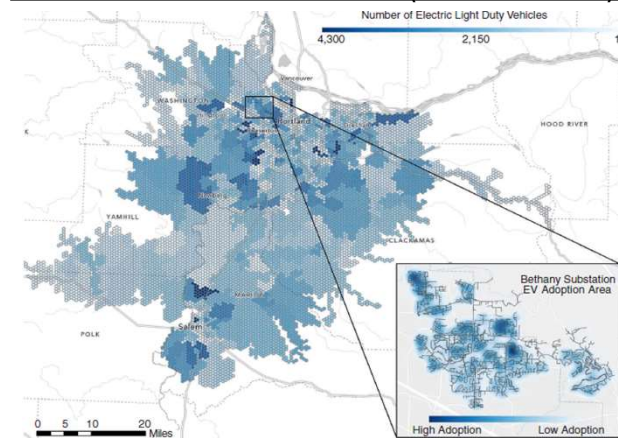
Forecast at a granular level by capturing the key variables

- **Adoption:** How many and when will people switch to EVs? Backcasting can help
- **Use Case:** Differentiate how a particular vehicle will be used across the year
 - School buses vs. city buses
 - Commuter vs. secondary vehicles
- **Technology:** Capture trends, such as larger batteries with faster charging.
- **Scenarios:** Use multiple futures that stress the system in different ways

Use Cases – Current LDVs¹



Differs across service areas (Portland, OR)²



¹NREL, 2023. *The 2030 National Charging Network*

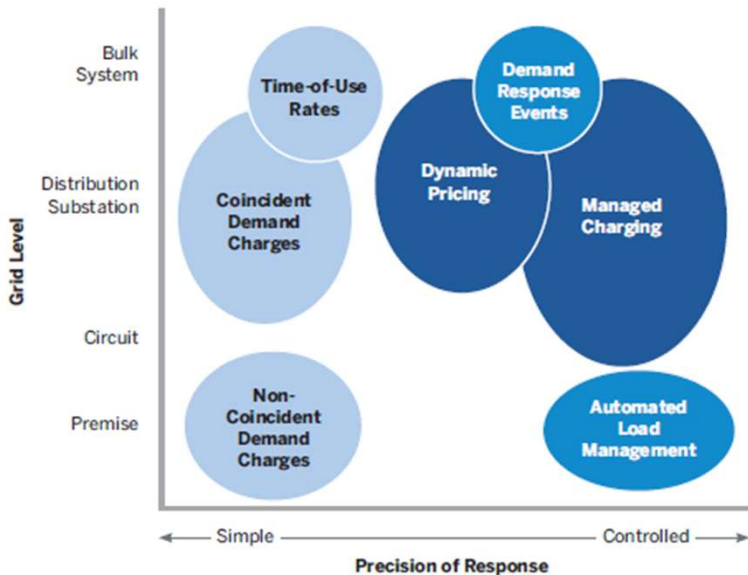
²PGE, 2023.

Embrace Smart Charging:

Many Flavors of Smart Charging – pricing, control, preset, and dynamic



- Traditional assumptions for what can be accomplished with demand flexibility should be re-evaluated in the context of EVs.
 - San Diego Gas & Electric observed that 77% to 87% of charging happened off-peak.¹
 - TOU pilots from 2008-2012 targeting the whole home resulted in a 2% to 21% peak reduction.²
 - UK study showed participants with EVs reduced peak by 47% compared to 28% for non-EV drivers.³



Mitigation Measure	Classification		Suitability to Address Challenges at Multiple Levels				Ease of Implementation	Cost
	Signal	Timing	Site	Distribution	Transmission	Generation		
Demand charge	Pricing	Preset	Light	Light	Light	Light	Light	Light
Time-of-use rate	Pricing	Preset	Light	Light	Light	Light	Light	Light
Dynamic price signal	Pricing	Dynamic	Light	Light	Light	Light	Dark	Dark
Consumer response to event-based demand response	Control	Dynamic	Dark	Dark	Light	Light	Dark	Dark
Dynamic managed charging	Control	Dynamic	Light	Light	Light	Light	Dark	Dark
Automated load management	Control	Preset	Light	Light	Dark	Dark	Dark	Dark

More to less suitable ▶▶▶
Less to more complex ▶▶▶

Cost and ease to implement smart charging measures are characterized relative to each other and should be evaluated against alternatives, such as infrastructure improvements.

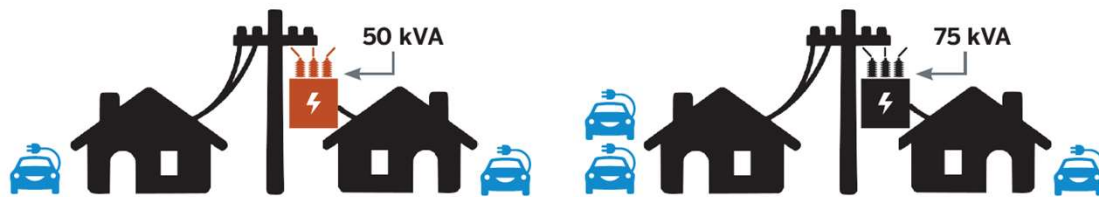
©2024 ESIG. All rights reserved.

Image Sources. Energy Systems Integration Group. 1. Cutter et al., 2021. 2. Badtke-Berkow et al., 2015. 3. Octopus Energy, 2019.

Incorporate Future-Ready Equipment: Use Infrastructure that can support the future



Equipment Standards



Exegol Utility District

When equipment is a candidate for replacement, the utility replaces legacy designs with similar design standards that may become overloaded with incremental EVs.

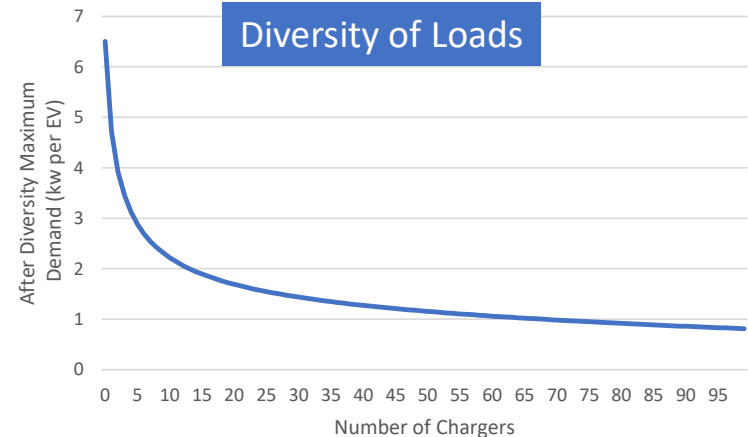
Tatooine Cooperative

When equipment is a candidate for replacement, either at end of life or when the utility is doing things like pole replacement, the utility replaces legacy designs with future-ready solutions.

Equipment Standards are used to streamline inventory, installations, engineering, etc.

- Can direct decisions about:
 - Voltage class: 4kV->12kV->26kV
 - Equipment sizing: 50 kVA ->75kVA transformer for 10 customers
 - Land parcel procurements: square footage required for substations

Diversity of Loads



Diversity of Loads inform equipment sizing

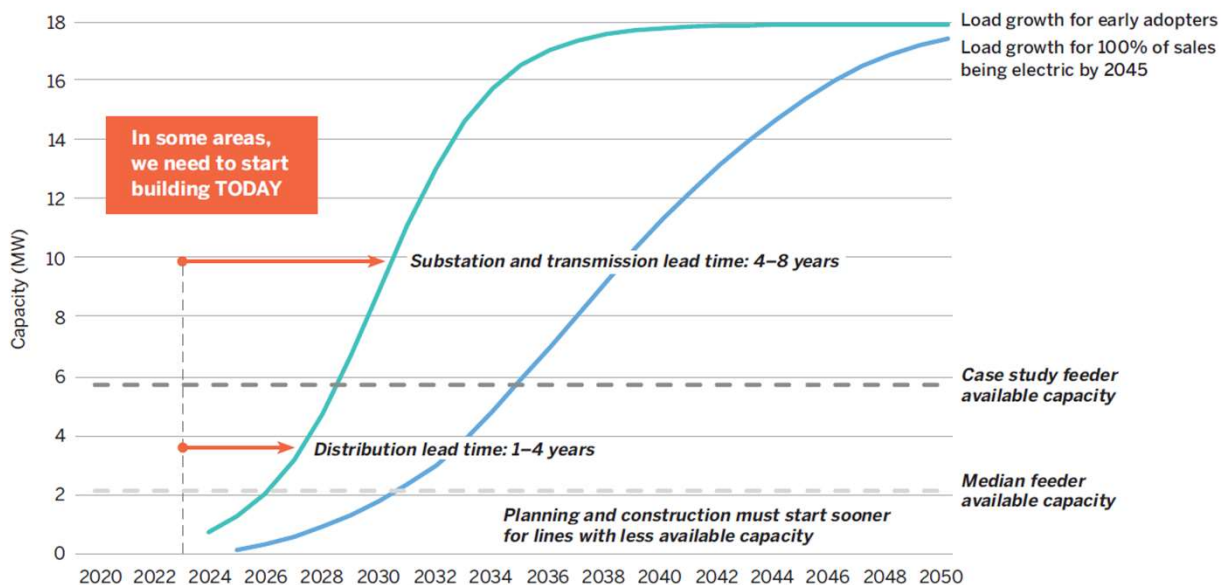
- Example: Pat charges on Tuesday, Sam on Wednesday, so grid equipment is sized for one EV
- EVs are new, so diversity needs to be calculated
 - Coordinate with smart charging designs ³⁰
 - Coordinate with loss of equipment life strategy

Image Sources: Top: ESIG; Bottom: Data from Vector

Promote Proactive Upgrades: Getting Proactive, but intelligently



Future-ready grid upgrades that take place over decades will not be sufficient to meet all projected EV charging needs. Some locations may need upgrades today. Widespread just-in-time upgrades of distribution equipment to support the level of electrification projected would be both costly and infeasible for utility construction crews.



Risks:

- Unreliable grid
- Stunted public interest in EVs
- Long waits for charger installs

Risks:

- Expensive underutilization
- Inequitable burden of costs

Practice and Process Adaptations



Align the Grid Planning Process with the Need



Existing Processes

While today's grid planning processes vary across the country, they generally include:

- Annual system reviews
- Regularly updated grid plans with a medium- to long-term planning horizon
- Isolated evaluation of interconnection requests

Customer-Collaborative Processes

A customer-collaborative process between planners and customers allows for open communication about:

- Multiple options for interconnection
- Multiple locational alternatives

Proactive, Multi-Stakeholder Processes

Given the volume and multiple use cases of EVs, proactive processes can be well suited to:

- Ensure equity
- Facilitate regional networks
- Provide clear roadmaps for electrification planning progression

Given the scale of grid planning for vehicle electrification, new processes can help

- Even with the best planning practices (what the grid engineer can do), process changes can enable more effective and holistic grid planning for EVs.
- Regulatory and policy support will be needed for proactive upgrades.

When to Use Which Process

Shading indicates suitability of process to address EV Need



Managed Charging of Light-Duty Vehicles		
Existing processes	Customer-collaborative processes	Proactive processes
<ul style="list-style-type: none"> • Daily-routine charging • Demand for L1 charging • Elastic demand 	<ul style="list-style-type: none"> • Perceived charging deserts • Service provider requests 	<ul style="list-style-type: none"> • High vehicle deployment • Heavily loaded distribution • Inflexible demand

Charging Along Highways and Corridors		
Existing processes	Customer-collaborative processes	Proactive processes
<ul style="list-style-type: none"> • Minimal highway usage 	<ul style="list-style-type: none"> • Along private highways 	<ul style="list-style-type: none"> • Grid limitations along highways • Regional EV growth • Interregional trucking

Charging of Vehicle Fleets		
Existing processes	Customer-collaborative processes	Proactive processes
<ul style="list-style-type: none"> • Small fleets • Sufficient highway charging 	<ul style="list-style-type: none"> • Inflexibility in timing and location • Large fleets 	<ul style="list-style-type: none"> • Multiple fleets competing for capacity • Limited land availability

Charging in Underserved Communities		
Existing processes	Customer-collaborative processes	Proactive processes
<ul style="list-style-type: none"> • Equity considerations included • Incentives for EV purchase and smart charging 	<ul style="list-style-type: none"> • New multi-family housing 	<ul style="list-style-type: none"> • Insufficient opportunity for charging • MHD vehicles near communities

Summary and Key Points



- **Lots of unknowns, but decisions are needed today**
 - Opportunities to improve forecasting
 - Opportunities to shape customer perception
- **Smart Charging will be helpful**
 - Learn how to rely on it in grid planning
 - Prioritize infrastructure where demand management cannot defer investment
- **Many grid planning improvements are outside of normal activities:**
 - Future-ready systems – reconsidering design standards
 - Proactive upgrades with uncertainties
 - Collaborative and multi-stakeholder processes



THANK
YOU

Sean Morash

Sean.morash@telos.energy

ERCOT EV ALLOCATION STUDY

*METHODOLOGY FOR DETERMINING EV LOAD IMPACT AT
THE SUBSTATION LEVEL*

PRESENTED BY

Sanem Sergici, Ph.D.

PRESENTED FOR

NARUC EV State Working
Group

JUNE 2024



EV sales have risen significantly in the U.S., but deployment remains uneven across states

As of March 2024, total EVs on the road in the U.S. was roughly 3.3 million vehicles, up from 2 million in 2022 (*)

2030 projections range from 10–45 million EVs create significant uncertainty for system planners

Planners will have to **develop location-specific EV forecasts** and identify key drivers of EV sales to inform system planning

- Forecasts should account for local considerations, such as state and utility incentives, ZEV goals, HOV lanes, EV sales trends, fuel prices, and charging infrastructure availability
- EV forecasts can also provide insights into effectiveness of incentives to accelerate EV adoption in their market

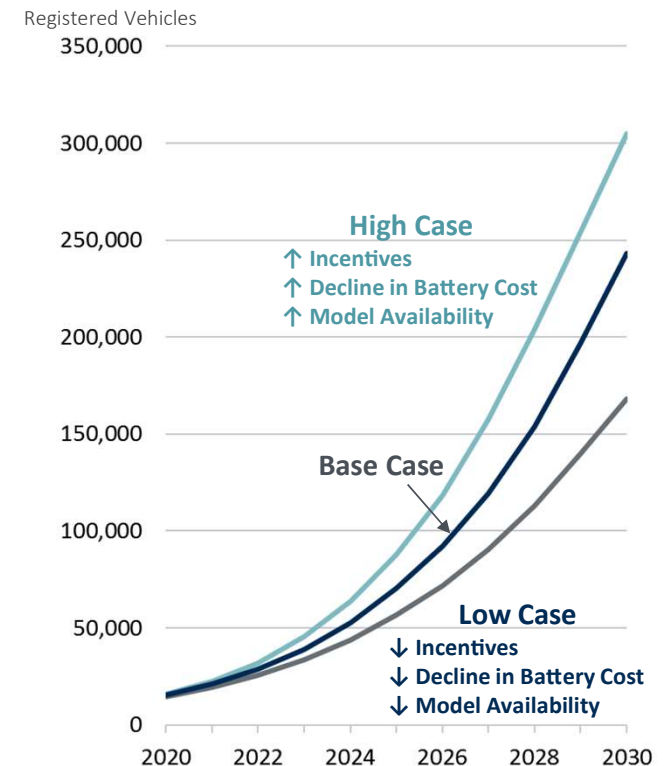
What has been driving EV adoption so far?

Based on a study of 12 years (2011 through 2022) of monthly EV sales across all 50 states, **Brattle's Econometric EV Adoption Model** yields several important insights

- **Vehicle Incentives**
\$1,000 increase in total incentives increases EV sales by 3.2%
- **Charging Infrastructure**
10% increase in public ports increases EV sales by 0.3%
- **Battery Price**
\$10/kWh decrease in battery price increases EV sales by 4%
- **Fuel Costs**
10% decrease in “fueling” cost savings increases EV sales by 6%
- **Model Availability**
Every 10 additional EV models increase EV sales by 2%

The Econometric EV Adoption Model can generate **location-specific EV forecasts** that are calibrated to local market conditions and able to **identify cost-effective incentives** to increase EV adoption

Example Output of Brattle's Econometric EV Adoption Model



ERCOT EV Allocation Study



- The Brattle Group was retained by ERCOT to create and carry out a repeatable process for forecasting electric vehicle load impacts at the substation level out to 2029, for use in their System Planning Assessment
- ERCOT requested an interactive “tool” that could be used to easily replicate and update the analysis in the future
- Brattle has conducted a thorough review of ERCOT’s existing electric vehicle assumptions, allocated those forecasts to ERCOT substations using Texas-specific and publicly accessible data, and generated representative 24-hour load profiles at each of roughly 4,000 substations for 8 years, 4 seasons, and 2 day-types
- Brattle has also corresponded at length with several of ERCOT’s Transmission and Distribution Service Providers to gain perspective on their plans for EV adoption in the next 8 years

Step 1: Forecasting ERCOT EV Adoption



1 Establish Light, Medium, and Heavy-Duty EV Adoption Forecasts for 2022-2029

- Update and improve upon ERCOT's existing adoption assumption for LDV penetration.
- Build out adoption forecast for a more granular list of Medium and Heavy-Duty (MHDV) EVs

2 Allocate Adoption Forecasts to ERCOT Substations

- Separate methodologies for LDV and MHDV allocation
- Vehicles first allocated to the zip-code level and then to the substation-level using data from ERCOT, the Census, and Moody's.

3 Calculate Load Impacts at the Substation-Level

- Calculate 64 representative load profiles for each substation, showing load throughout 4 seasons, 2 day types, and 8 years.
- Develop interactive tool that generates profiles for each substation and can be easily updated in the future.

Adjustments to ERCOT Forecasts for LDVs and MHDVs



We implemented small adjustments to ERCOT’s LDV forecasts

We group MHDVs into 5 classes, which largely align with the Federal Highway Administration’s gross vehicle weight ratings (FHWA GVWR) and ERCOT’s vehicle class segmentation.

- These classes were selected to align with the classes used for EV sales adoption forecasts in Brattle’s Delphi Survey.
- We add additional granularity to ERCOT’s breakdown by adding more categories to their Local HD class.
- We consider buses and school buses separately from the weight classes.

Weight less than or equal to (lbs)	6,000	8,500	10,000	14,000	16,000	19,500	26,000	33,000	60,000	over 60,000
FHWA GVWR Vehicle	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8		
ERCOT Vehicle Classes	Light Duty Trucks and Cars			Local HD				Long Distance HD		
Brattle Vehicle Classes			Class 2B	Class 3-4		Class 5-6		Class 7-8 Regional Class 7-8 Long Haul		

ALLOCATION

Step 2: Allocate EV Adoption to ERCOT Substations



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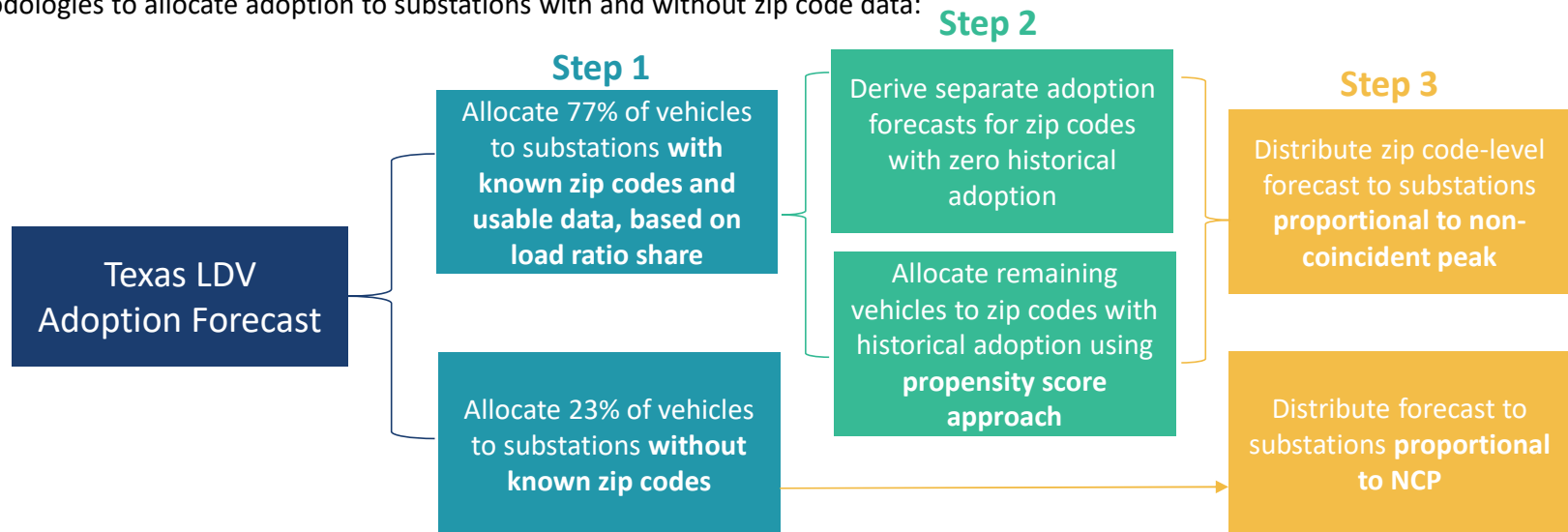
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LDV ALLOCATION METHODOLOGY

LDV Allocation Methodology

- The objective of this step in the analysis is to allocate our Texas-level LDV forecast to each of ERCOT's substations.
 - We first allocated adoption to all zip codes in ERCOT's service territory, and then further allocated to the substations serving each zip code.
- ERCOT Substations fall into three categories:
 - **ESIID Substations** – Existing ERCOT substations with loads associated with competitive choice areas within ERCOT.
 - **NOIE Substations** – Existing ERCOT substations with loads associated with Non Opt-In entities within ERCOT.
 - **Planned Substations**
- From ERCOT, we received a mapping of ESIID substations to the zip codes they serve, as well as non-coincident peak forecasts (in MW) for each substation. ERCOT does not track the zip codes served by Non Opt-In entities (NOIE) or Planned substations. For this reason, we applied varying methodologies to allocate adoption to substations with and without zip code data:

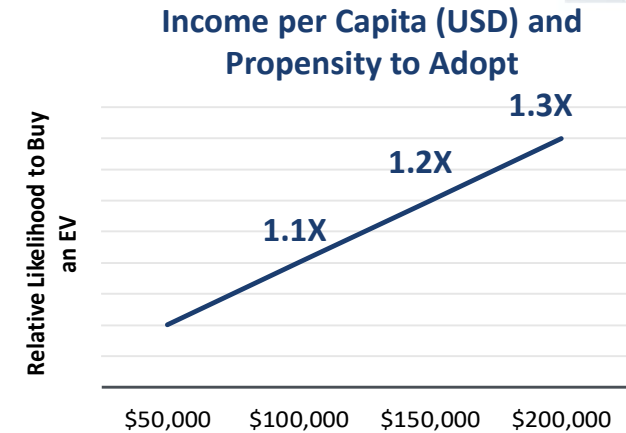


LDV ALLOCATION METHODOLOGY

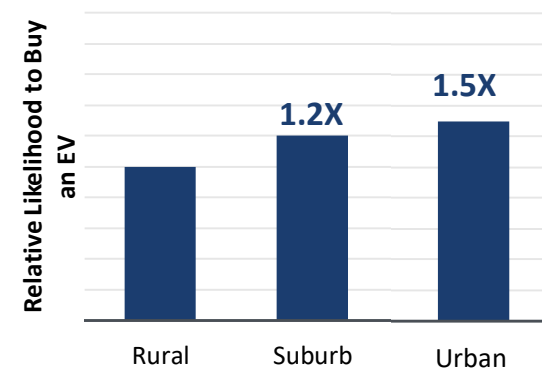
Step 2: Calculate “Propensity Score” for Each TX Zip Code

- A “Propensity Score” is a metric that calculates the likelihood of EV adoption in a given geographic area. We rely on this metric to determine where LDV adoption is most likely to occur across Texas in each of our forecasted years.
 - We forecast and assign a “propensity score” of EV adoption to each of the **1,935 active zip codes** in Texas for each year between 2022-2029.
 - Each zip code’s “score” is equal to the product of a number of key economic indicators specific to that zip code, as well as adjustments for historical EV adoption levels.
 - Once each zip code is assigned a score, we translate each zip code’s propensity score into a share of statewide adoption.
- According to prior Brattle work with EPRI, **income** and **population density** are two key indicators of a given geographic location’s propensity to adopt an EV. Additional propensity score considerations include:
 - Historical EV Adoption Levels to ensure that our propensity scores are well-aligned with the existing EV market in each zip code.
 - Total Registered Vehicles: We multiply each propensity score by the total number of vehicles registered in each zip code.

Propensity Score = Income per Capita Score × Population Density Score × Historical Adoption × Total Vehicle Registrations



Population Density and Propensity to Adopt



Source: McFadden et. al., The Impact of Incentives on Electric Vehicle Adoption: National Average Results. EPRI 2019.

LDV ALLOCATION RESULTS

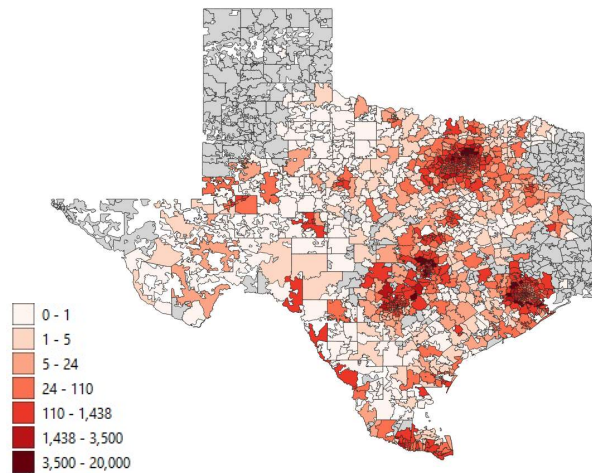
LDV Allocation: Summary of Results

- Our resulting allocation concentrates adoption primarily in urban and suburban zip codes surrounding major cities. The highest adoption zip codes in 2029 all started out with relatively high adoption in 2022.
 - Note that these values do not include additional adoption that may be served by NOIE or Planned substations.
 - Once the TX zip codes are pared down to just ERCOT zip codes, we find that **96%** of LDVs adopted in TX will fall in ERCOT's service territory.

Top 10 Zip Codes by LDV Adoption in 2029

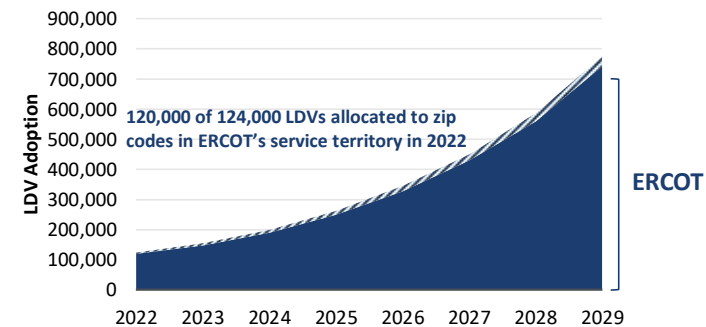
Rank	Zip Code	Current (2022) Adoption Level	2029 Adoption	Nearest City
1	77479	1,401	16,638	Houston
2	78613	1,130	12,501	Austin
3	75034	959	11,305	Dallas
4	75035	1,438	11,084	Dallas
5	77494	1,027	10,083	Houston
6	78660	892	8,740	Austin
7	75070	709	8,589	Dallas
8	78665	642	7,329	Austin
9	77584	589	7,046	Houston
10	78704	1,068	6,712	Austin

2029 LDV Allocation by Zip Code



Note: Figure is only showing adoption allocated to substations with zip code mappings. Adoption allocated to NOIE and Planned substations is not included, which is likely why some zip codes show 0 adoption.

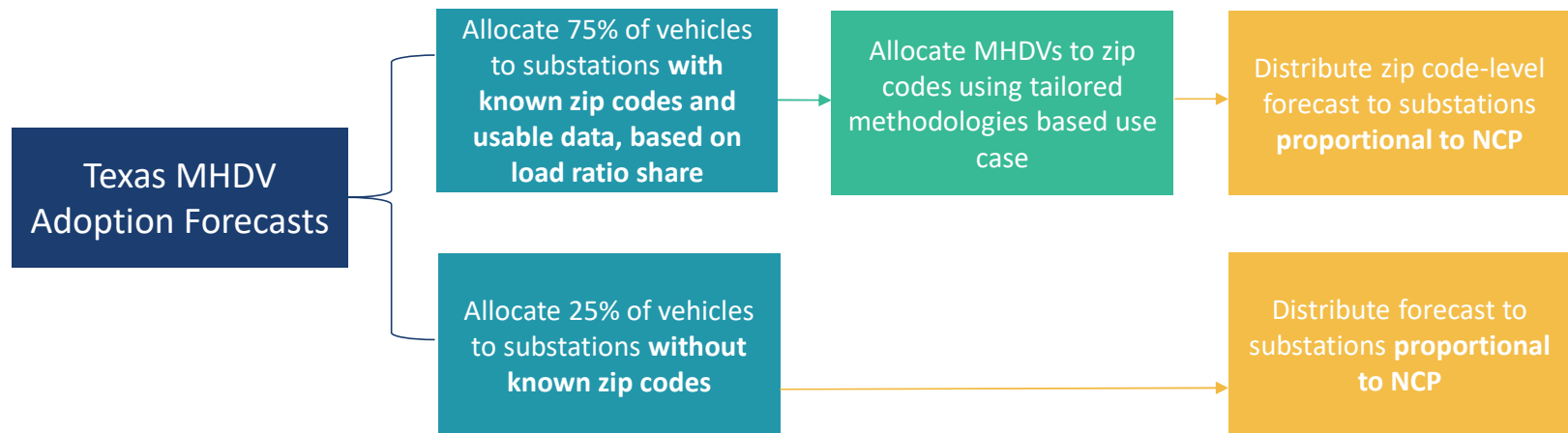
Texas-Wide EV Adoption



MHDV Allocation Methodology: Overview

As in the LDV methodology, we allocate 25% of vehicles directly to the NOIE substations proportionally to the NCP load served by those substations, because ERCOT does not track the zip codes served by these substations.

For the remaining 75% of vehicles, we developed a 4-step methodology to allocate MHDVs to zip codes and then to substations.



MHDV Allocation Methodology: Overview



We developed a 4-step methodology to allocate MHDVs to substations.

1. In the first step, we identify the primary use cases of each vehicle weight class.
2. Understanding use cases is key to elucidating the economic factors that affect MHDV locations, driving patterns, and electrification likelihood, which is step 2.
3. Once proxies and corresponding data sources are identified, we use them in step 3 to develop quantitative metrics to allocate vehicles in each class to zip codes and then substations.
4. Lastly, we produce data visualizations and assess the results in the context of acknowledged model limitations.

Proxies for MHDV Location and EV Adoption

We identified public data sources that inform estimation of:

1. Where MHDVs are located
2. Where EV MHDV adoption is likely

We use these identified proxies to develop a quantitative allocation metric for each method, A-G.

Allocation Method	1. Proxies for Vehicle Location	2. Proxies for EV Adoption Likelihood
A: Pickup Trucks	<ol style="list-style-type: none"> 1. Population Density 2. Number of LDVs 	<ol style="list-style-type: none"> 1. Population Density 2. Income
B: Regional Delivery Vehicles	<ol style="list-style-type: none"> 1. Employment in the transportation and warehousing industry 	<ol style="list-style-type: none"> 1. Distribution center locations
C: Dump Trucks	<ol style="list-style-type: none"> 1. Employment in mining and construction industries 	<ol style="list-style-type: none"> 1. Assumed uniform adoption likelihood across zip codes
D: Regional Heavy Duty Trucks	<ol style="list-style-type: none"> 1. Employment levels in the transportation and warehousing industry 2. Truck traffic on roads 3. Corridor charging station locations 	<ol style="list-style-type: none"> 1. Distribution center locations
E: Long Haul Heavy Duty Trucks	<ol style="list-style-type: none"> 1. Truck traffic on major roads 2. Corridor charging station locations 	<ol style="list-style-type: none"> 1. Assumed uniform adoption likelihood across zip codes
F: Transit Buses	<ol style="list-style-type: none"> 1. Buses registered at a transportation authority level 2. Population 	<ol style="list-style-type: none"> 1. Population density 2. Income
G: School Buses	<ol style="list-style-type: none"> 1. Population of school aged children 2. Population density 	<ol style="list-style-type: none"> 1. Population density 2. Income

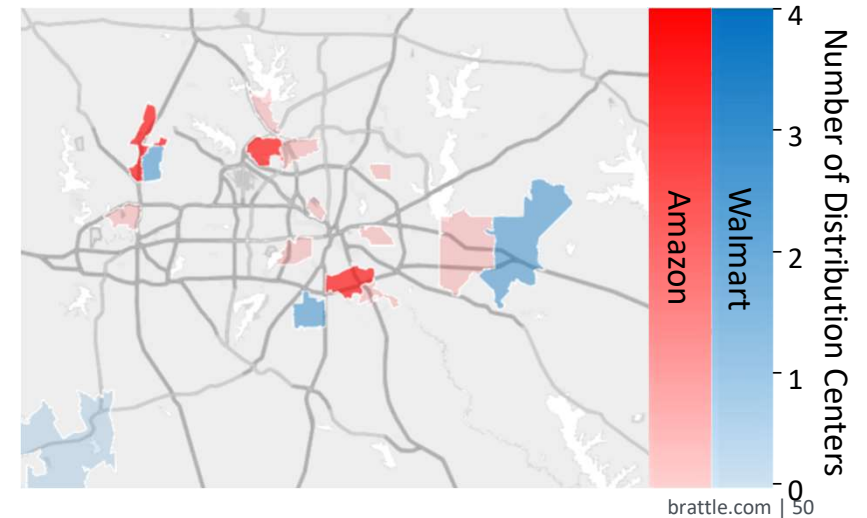
Additional Detail: Distribution Center Approach

- We identified companies in Texas expected to be early or major adopters of EVs based on information from TDSPs and ERCOT.
- For straight truck allocation, we consider the warehouses of Walmart, HEB, Frito Lay, Amazon, UPS, and FedEx. For cargo and step van allocation, we only consider Amazon, UPS, and FedEx locations.

Expected Early or Major Adopters of Electric Trucks by TDSPs

	CPS	Oncor	TNMP	Austin Energy
Consumer Goods	Walmart, AT&T, Verizon, Ikea	Amazon	Amazon	Amazon, Ikea, Staples, J.B. Hunt
Food	Frito Lay, Pepsi	Frito Lay		Frito Lay, Coca Cola, Pepsi, Nestle
Transport	UPS	FedEx, UPS, Ryder		DHL, UPS, FedEx, USPS

Amazon and Walmart Distribution Center Density in DFW Area

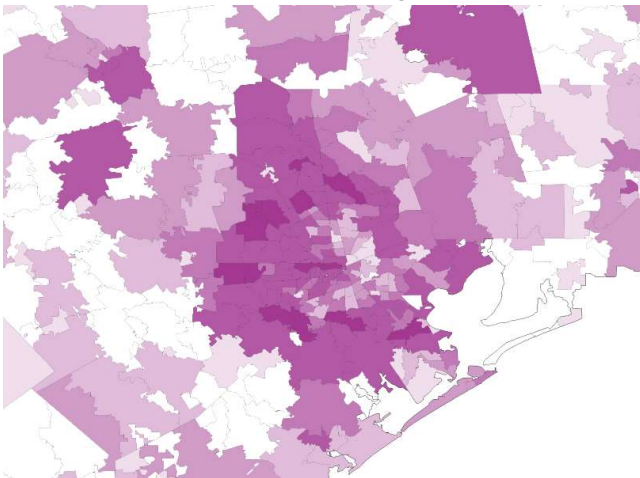


MHDV ALLOCATION RESULTS

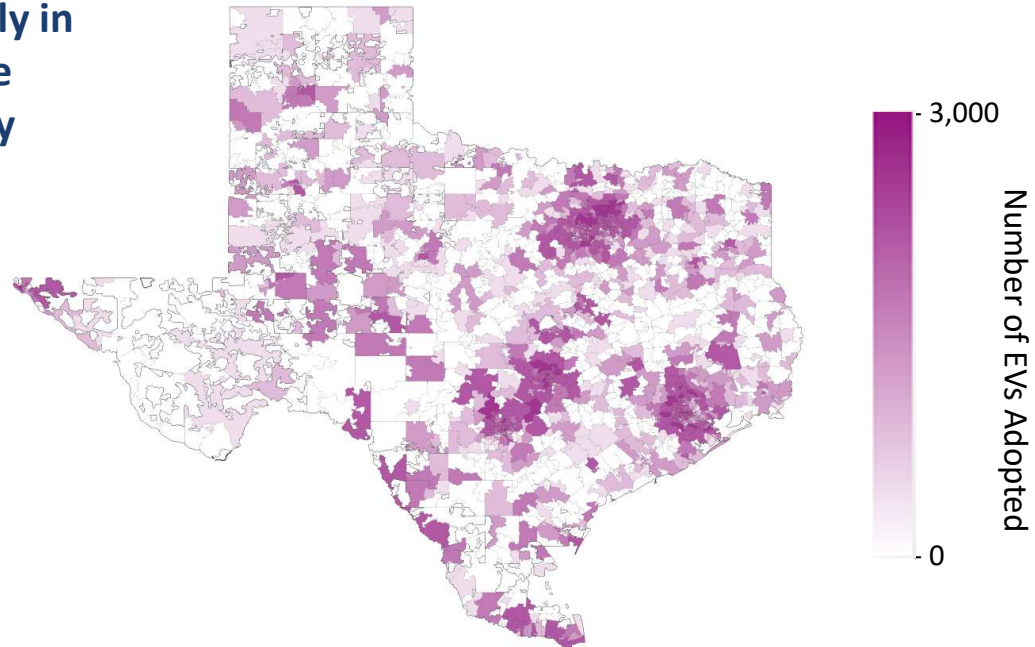
Results: Pickup Trucks

Pickup truck ownership is more common in rural areas. However, conditional on owning a pickup truck, an individual buying an electric pickup truck is more likely in urban areas. Combining these two factors, we see the highest EV pickup truck adoption in suburban and city outskirts zip codes.

Forecasted EVs by Zip Code Detail: Houston
2029, Pickup Trucks



Texas Forecasted EVs by Zip Code
2029, Pickup Trucks

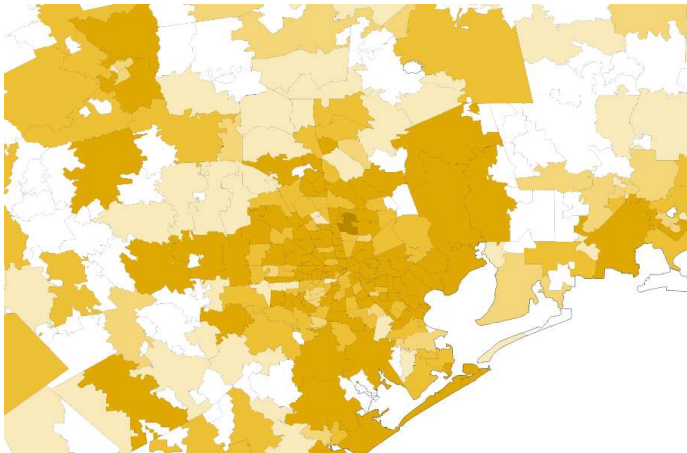


MHDV ALLOCATION RESULTS

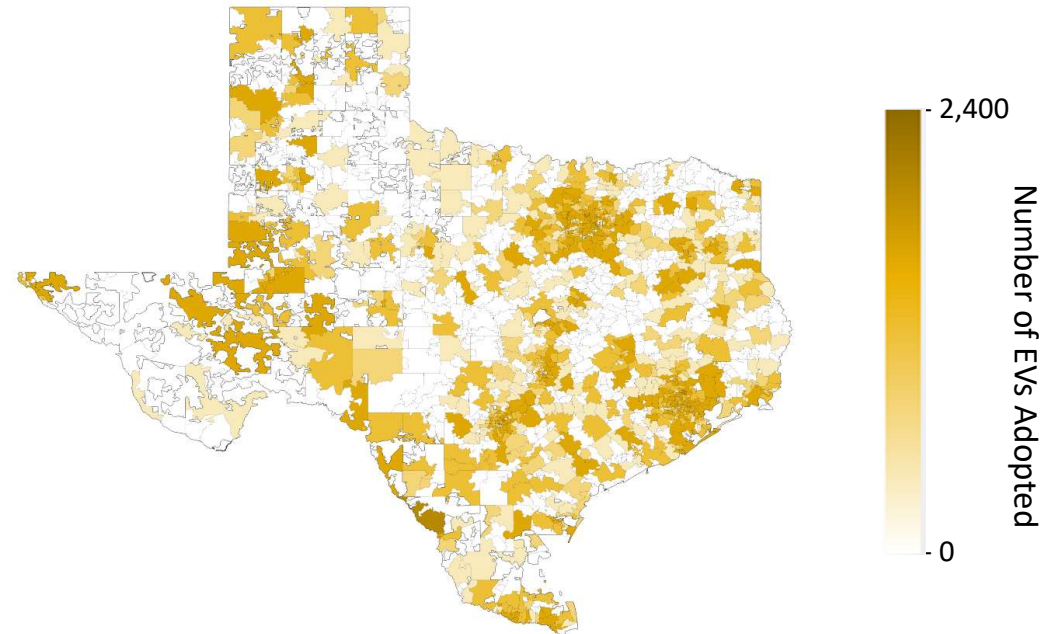
Results: Regional Delivery Vehicles

Electric regional delivery vehicle adoption is projected to occur around city outskirts and along major highways where distribution centers tend to be located.

Forecasted EVs by Zip Code Detail: Houston
2029, Regional Delivery Vehicles



Texas Forecasted EVs by Zip Code
2029, Regional Delivery Vehicles



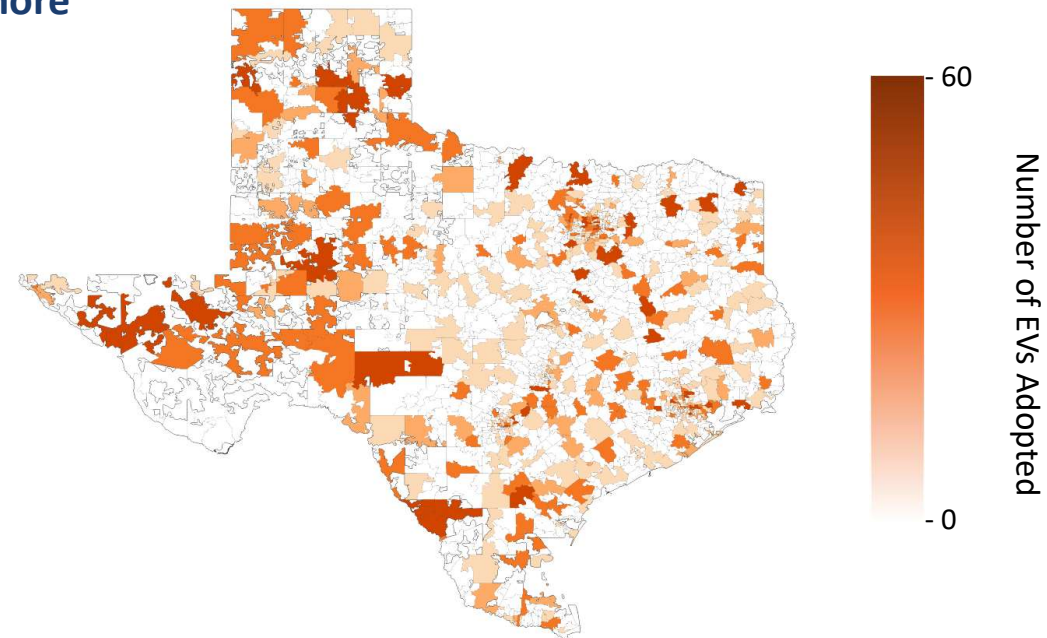
MHDV ALLOCATION RESULTS

Results: Regional Heavy Duty Trucks

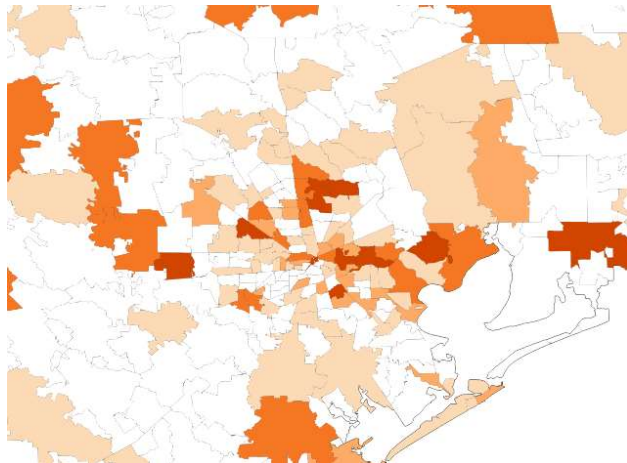
Electric regional trucks are projected to be located around city outskirts and along major highways where distribution centers tend to be located and where more large trucks tend to drive.



Texas Forecasted EVs by Zip Code
2029, Regional Heavy Duty Trucks



Forecasted EVs by Zip Code Detail: Houston
2029, Regional Heavy Duty Trucks



MHDV ALLOCATION RESULTS

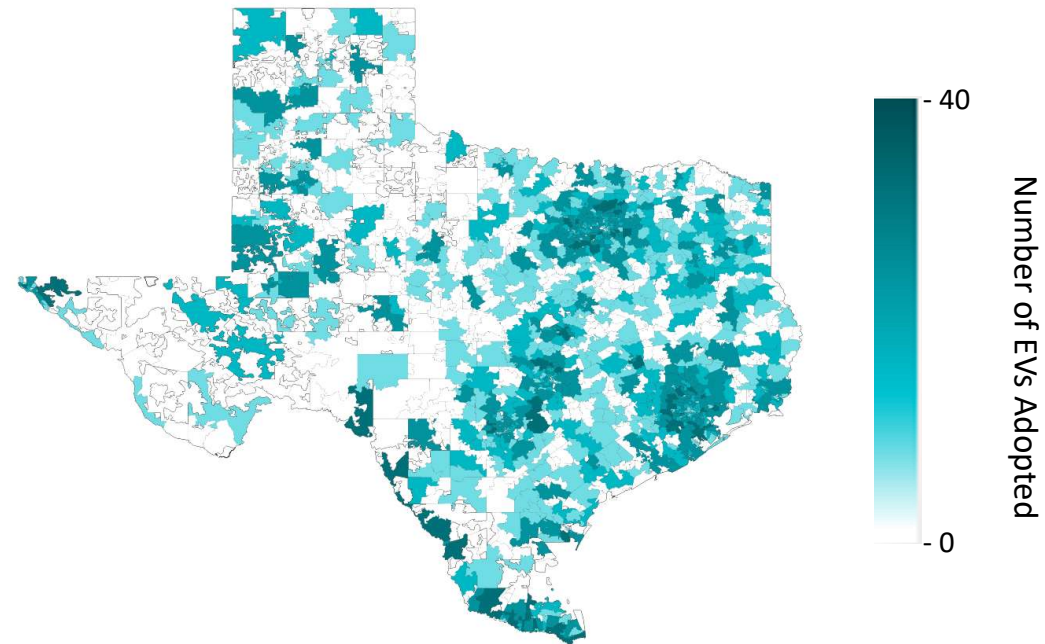
Results: School Buses

We project the most electric school bus adoption in suburban areas where children are more likely to ride the school bus and where there may be more public support for EV adoption among higher income households living in high density zip codes.

Forecasted EVs by Zip Code Detail: Houston
2029, School Buses



Texas Forecasted EVs by Zip Code
2029, School Buses

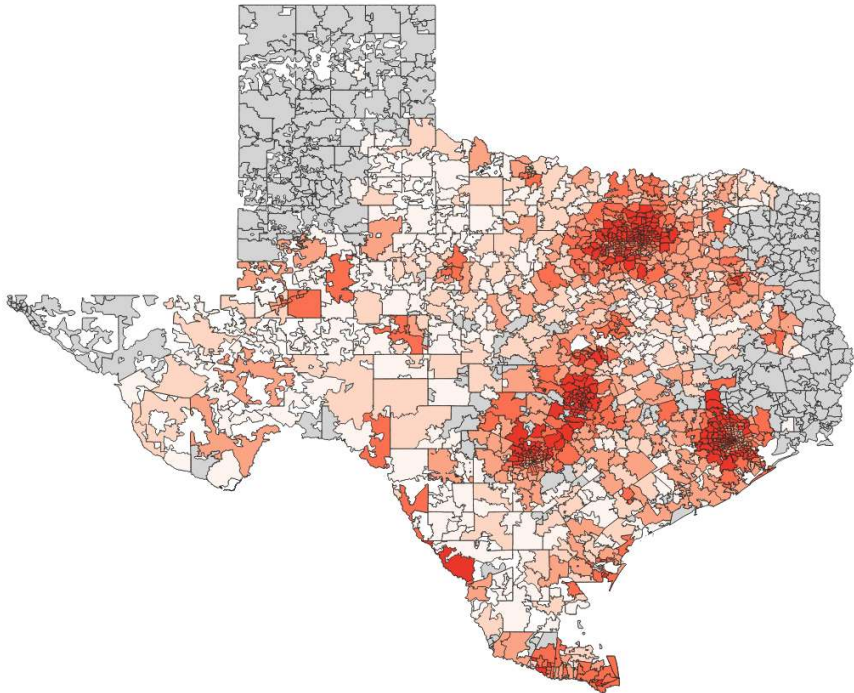


LDV AND MHDV ALLOCATION RESULTS

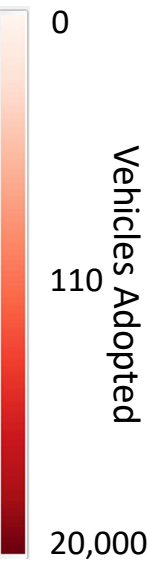
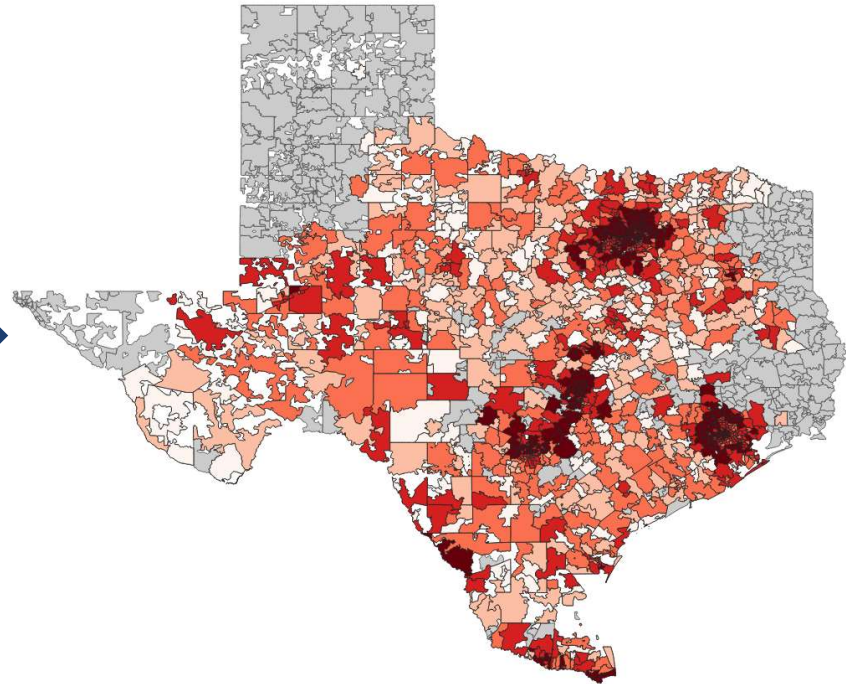
Final Electric Vehicle Allocation to ERCOT Zip Codes



2022 Electric Vehicle Adoption



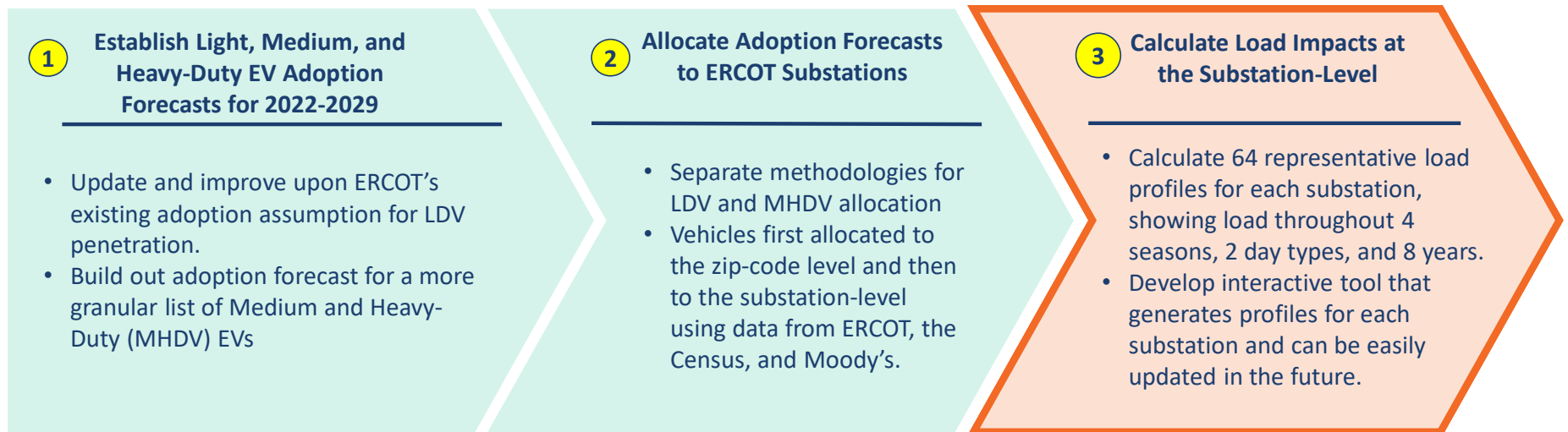
2029 Electric Vehicle Adoption



Note: Showing actual LDV adoption as of April 2022 via Atlas EV Hub. MHDV adoption is currently very low in TX (~50 EVs total) and is not shown on the figure.

Note: Showing modeled LDV and MHDV adoption in 2029. LDV adoption includes only vehicles allocated to ESIID substations (75% of forecast). Due to data limitations we cannot show the location of LDVs allocated to NOIE/Planned substations serving these zip codes.

Step 3: Load Impacts at the Substation-Level



LOAD IMPACTS

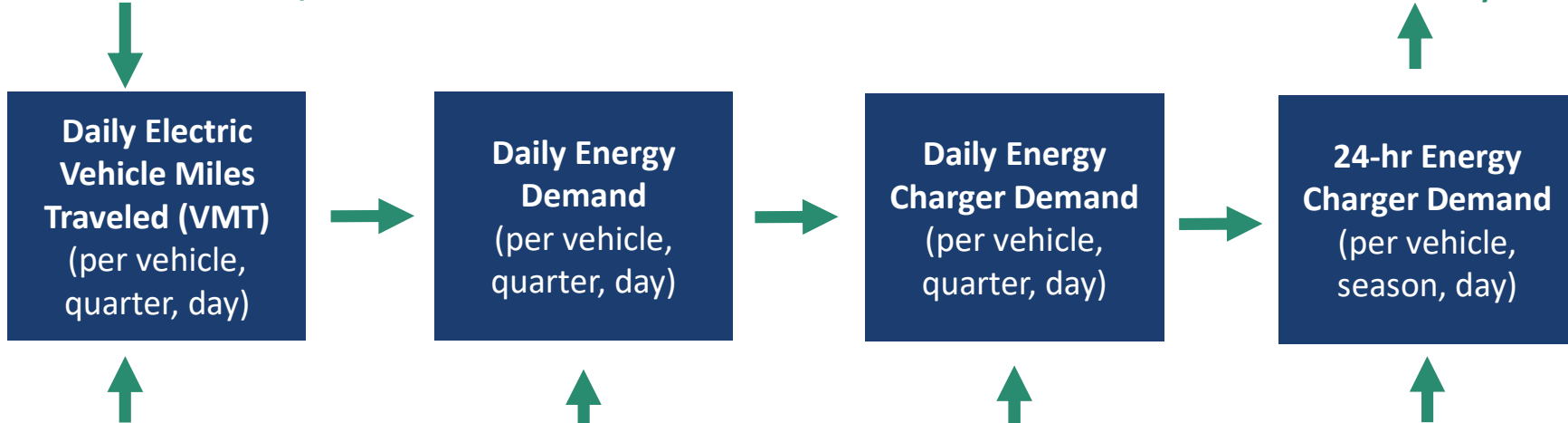
EV Load Profile Model Flow

Primary Texas-specific inputs:

- Total EVs
- Mix of EV types (Battery Electric (BEV)/Plug-in Hybrid (PHEV), sedan/SUV, battery size)

Output:

- Total hourly EV demand at each substation by season/day
- Can break down load by location/charging type



Inputs:

- % electric miles for PHEV
- Daily VMT for TX LDV drivers
- Seasonal VMT (% of annual)
- Weekday vs weekend VMT

Inputs:

- Vehicle average efficiency
- Seasonal ambient temperature by Weather Zone
- Efficiency vs temperature

Inputs:

- % of demand by location, for each vehicle, season, and day

Inputs:

- 24 hour normalized demand by charger type for each vehicle and day

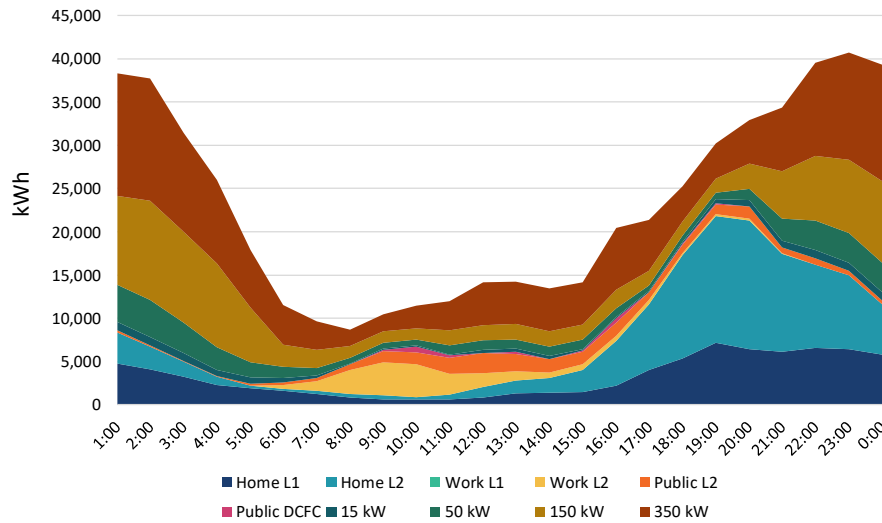
LOAD IMPACTS

Example Load Profiles

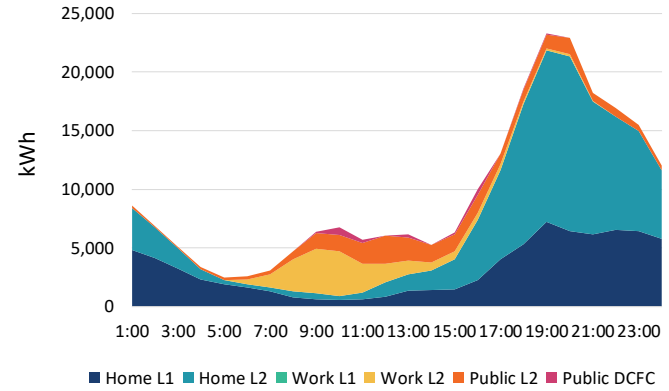
Takeaways: Our load profiles assume that substations will serve high levels of evening and overnight load due to charging from Long Haul trucks and LDVs plugging in at Home L2 chargers.



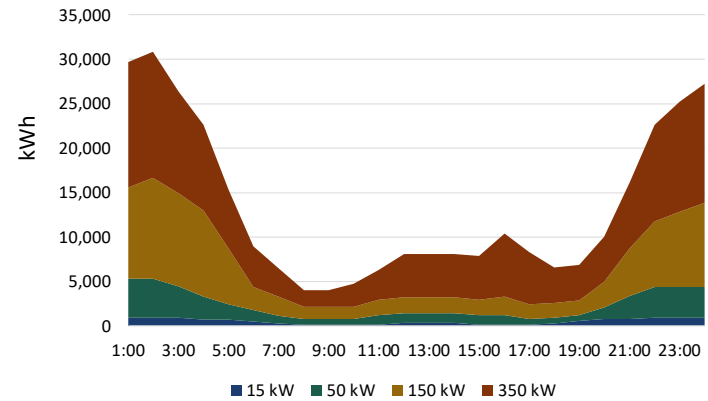
Spring Weekday Total EV Load (kWh)



Spring Weekday LDV Load (kWh)



Spring Weekday MHDV Load (kWh)



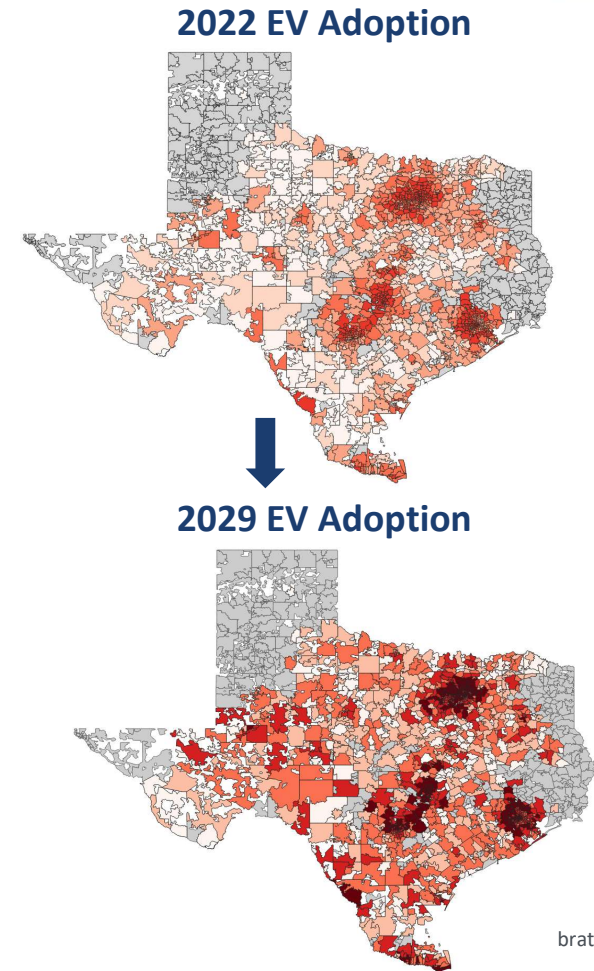
Summary of Results

- **System-wide adoption and load impacts:**

- ~770,000 LDVs and ~225,000 MHDVs are projected to be electric by 2029 in ERCOT's service territory, representing about **4%** of LDV stock and **6%** of MHDV stock, or **4%** of all vehicles on the road in TX. Approximately **96%** of electrified LDVs and **93%** of MHDVs across TX will be registered in ERCOT's service territory.
- The total EV charging load in 2029 is approximately **6.7 TWh**, adding **1.36%** of load to ERCOT's electric load forecast in 2029, up from **0.14%** in 2022 .

- **Allocation to substations:**

- LDV allocation is developed based on metrics capturing future propensity for adoption. Allocation is concentrated primarily in urban and suburban zip codes surrounding major cities such as Austin, Houston, DFW, San Antonio.
- MHDV allocation is established by multiple bottom-up models for key use cases. Delivery vehicles and regional and long haul trucks add load to substations in the city outskirts and major highways. Buses, pickup trucks, and certain regional trucks will increase load in urban and suburban areas.



Recap

- Brattle team developed a new methodology to allocate light, medium and heavy duty vehicles to ERCOT substations to understand the extent of additional load on substation peaks
- We utilized the most recent and best available information to guide our methodology, largely relying on publicly available data sources
- We took into account the characteristics as well as use cases for each vehicle category for defining an allocation method for that category
- This is still a very nascent research area, and there are not publicly available precedents to the allocation of EVs to more granular locations
- While our allocation method resulted in allocations consistent with a priori expectations (i.e. higher LDV allocations to urban and suburban zip codes surrounding major cities such as Austin, Houston, DFW and higher allocations of delivery vehicles and regional and long haul trucks add load to substations in the city outskirts and major highways), the accuracy of the approach should be evaluated periodically and adjusted as more data becomes available

Appendix



LDV Analysis Key Limitations

- Lack of zip code data for all substations causes us to make approximations for load at substations for which we do not know the associated zip code
- Approximation of adoption at zip codes with no historical adoption is speculative and assumes no-historical-adoption zips will experience adoption at a faster rate than zips with historical adoption
- List of active zip codes in TX and appropriate mappings to counties, census tracts, etc. is inconsistent across sources
- Propensity score approach could capture more economic variables in future iterations to produce more granular and diverse results across zips



MHDV Analysis Key Limitations



Allocation Method	Limitations and Areas for Future Development
Pickup Trucks	<ul style="list-style-type: none"> • Did not have pickup truck registrations at a county or zip code level- estimated based on a population density relationship.
Regional Delivery Vehicles	<ul style="list-style-type: none"> • In the future, could consider additional companies, distribution center size, and the specifics of expected announced adoption timelines.
Dump Trucks	<ul style="list-style-type: none"> • Did not identify centers where dump trucks are likely to charge • In the future, could add differentiation of EV adoption rates of dump trucks by zip code
Heavy Duty Trucks	<ul style="list-style-type: none"> • Assumed charging stations will be deployed as forecasted by the Texas DOT charging plan. • Assumed MHDV chargers will be deployed at the same rate and in the same locations as LDV chargers – MHDV report will be released this fall. • Assumed regional trucks will charge 50% along roads where they travel and 50% at distribution centers. • Assumed long haul vehicles will only charge along major highways.
Transit Buses	<ul style="list-style-type: none"> • Did not have information on bus depot and charging locations. • In the future, could incorporate information about which areas have announced electric bus adoption plans.
School Buses	<ul style="list-style-type: none"> • Did not have data on actual school bus registrations by zip code- estimated based on population density relationship. • Did not identify school bus charging locations or depots.

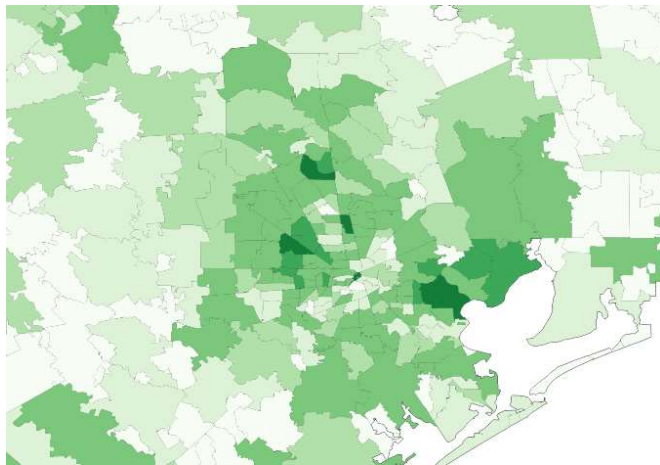
MHDV ALLOCATION RESULTS

Results: Dump Trucks

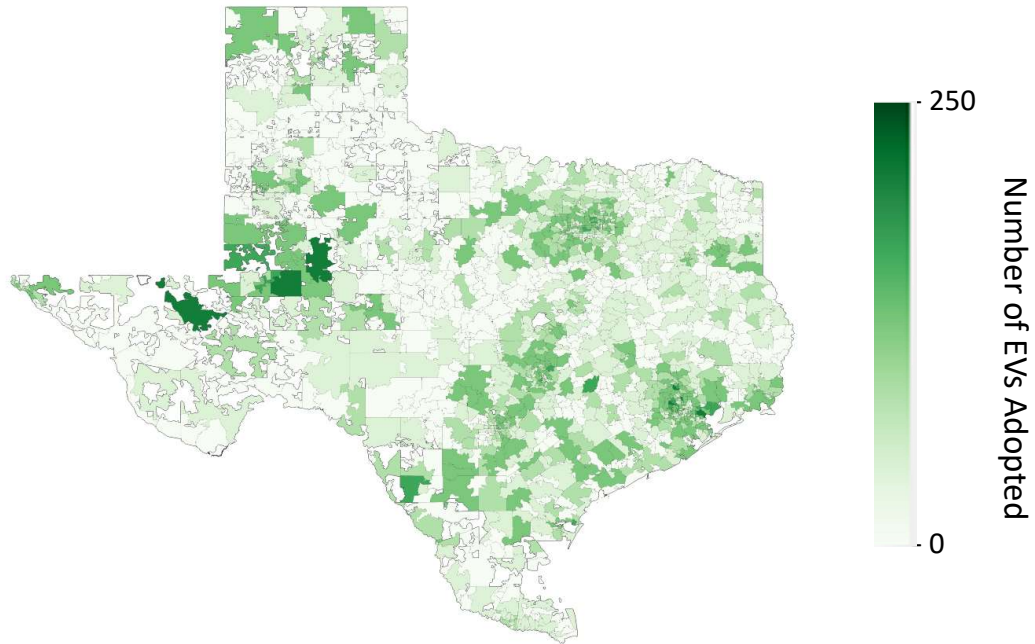
Electric dump truck adoption is generally clustered around cities.



Forecasted EVs by Zip Code Detail: Houston
2029, Dump Trucks



Texas Forecasted EVs by Zip Code
2029, Dump Trucks



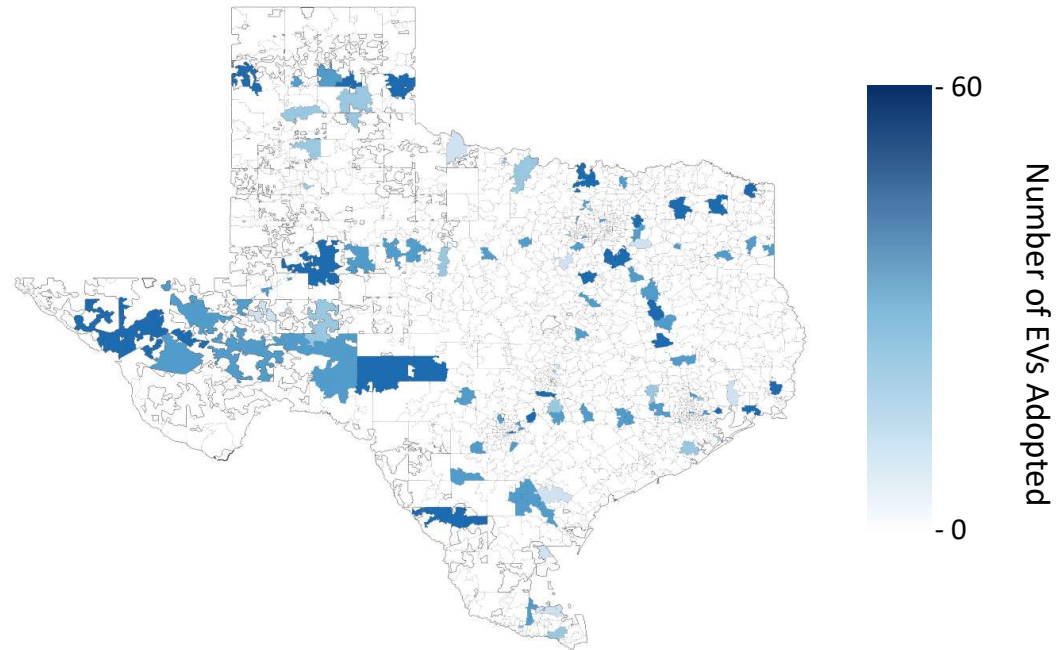
MHDV ALLOCATION RESULTS

Results: Long Haul Heavy Duty Trucks

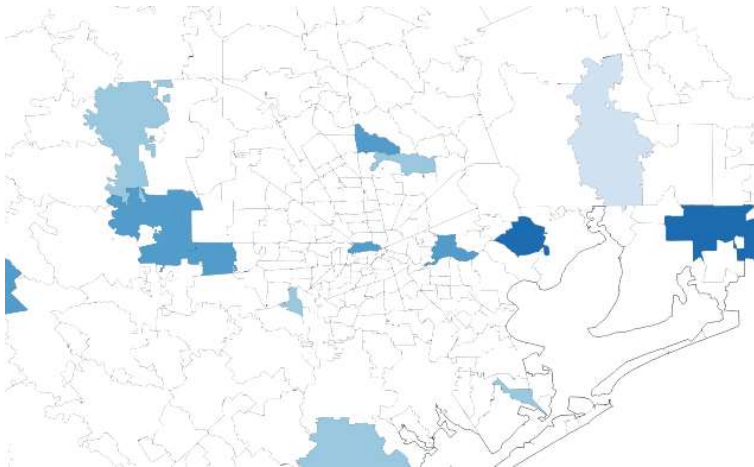
Electric long haul trucks are projected to be located along major highway corridors.



Texas Forecasted EVs by Zip Code
2029, Long haul Heavy Duty Trucks



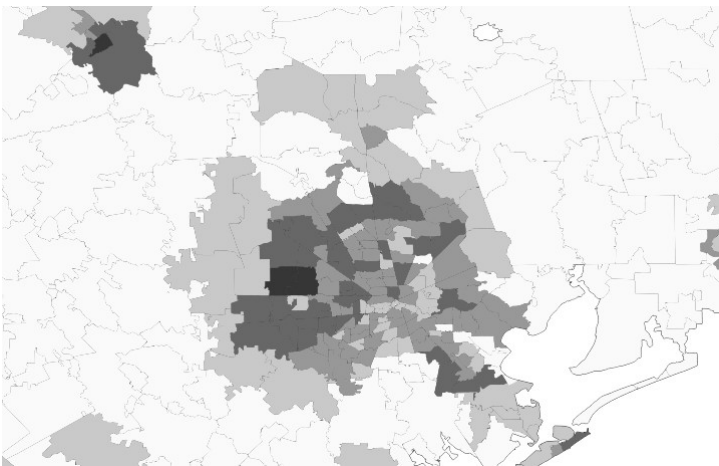
Forecasted EVs by Zip Code Detail: Houston
2029, Long Haul Heavy Duty Trucks



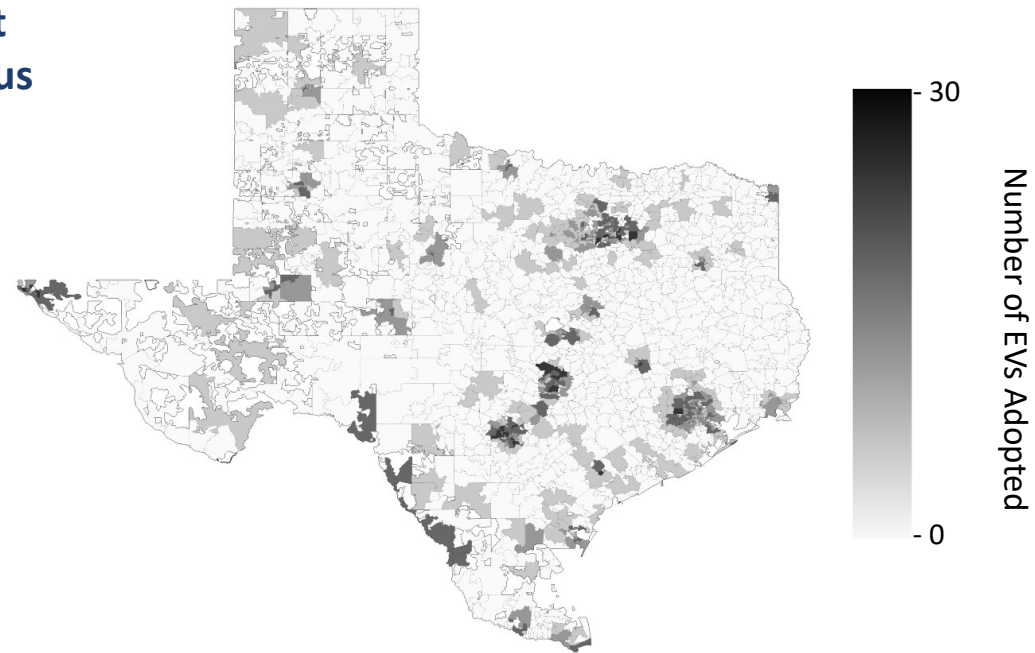
Results: Transit Buses

Electric transit bus adoption is expected to occur primarily in cities and areas with higher average income. Because depot charging locations were not identified, charging was assumed to occur where bus driving occurs.

Forecasted EVs by Zip Code Detail: Houston
2029, Transit Buses



Texas Forecasted EVs by Zip Code
2029, Transit Buses



Questions

Moderator: Commissioner Milt Doumit, Washington Utilities and Transportation Commission

Guest Speaker

- Paige Jadun, National Renewable Energy Laboratory (NREL)
- Sean Morash, Telos Energy
- Sanem Sergici, the Brattle Group

Member EV Roundtable

Please speak up and share the situation from your perspective:

1. What kind of scenarios are you seeing / considering in distribution/transportation electrification forecasting?
2. What solutions are your utilities considering / proposing to meet transportation electrification load growth projections? Are you seeing "no regrets" mentions / discussions?
3. Is your commission hearing about utilities wanting to invest proactively in infrastructure to meet future needs? If so, how is your commission handling?

Upcoming 2024 EVSWG Topic

Date (Last Tues of the month)	Future 2024 EV SWG Topics (through June)
July 30, 2024	Equity and access to charging
August 27, 2024	Air Quality Offices and Regulator Collaboration and EPA EV rules

Next EV SWG
meeting:
July 30, 3:00-4:30 pm
ET via Zoom

WWW.NARUC.ORG/CORE-SECTORS/ENERGY-RESOURCES-AND-THE-ENVIRONMENT/ELECTRIC-VEHICLES/