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March 24—27, 2025

Dallas, Texas

EXPERIENCE THE ENERGY MOVEMENT

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Forecasting EV Charging Demand on the Distribution System

Grid Planning for Rapid Growth with Xcel Energy

DISTRIBUTECH 2025: Dallas, Texas

March 25, 2025

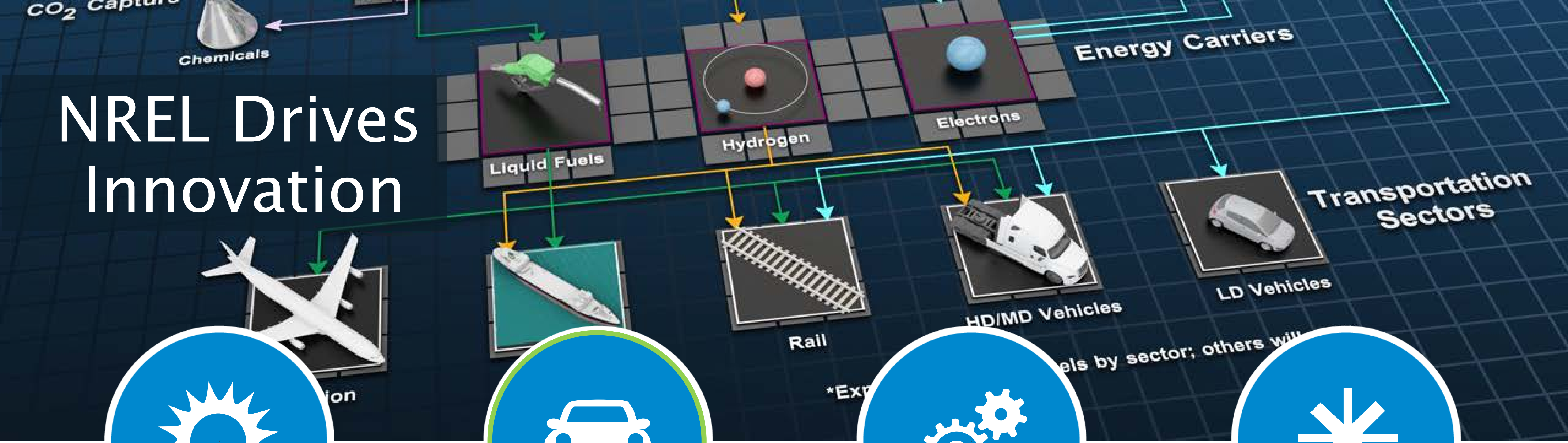
Brennan Borlaug

National Renewable Energy Laboratory

NREL

NREL: 3,000+ workforce dedicated to energy innovation and integrated energy systems research

NREL Drives Innovation



Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Electrification

Hydrogen

Energy Efficiency

Buildings

Advanced Manufacturing

Government Energy Management

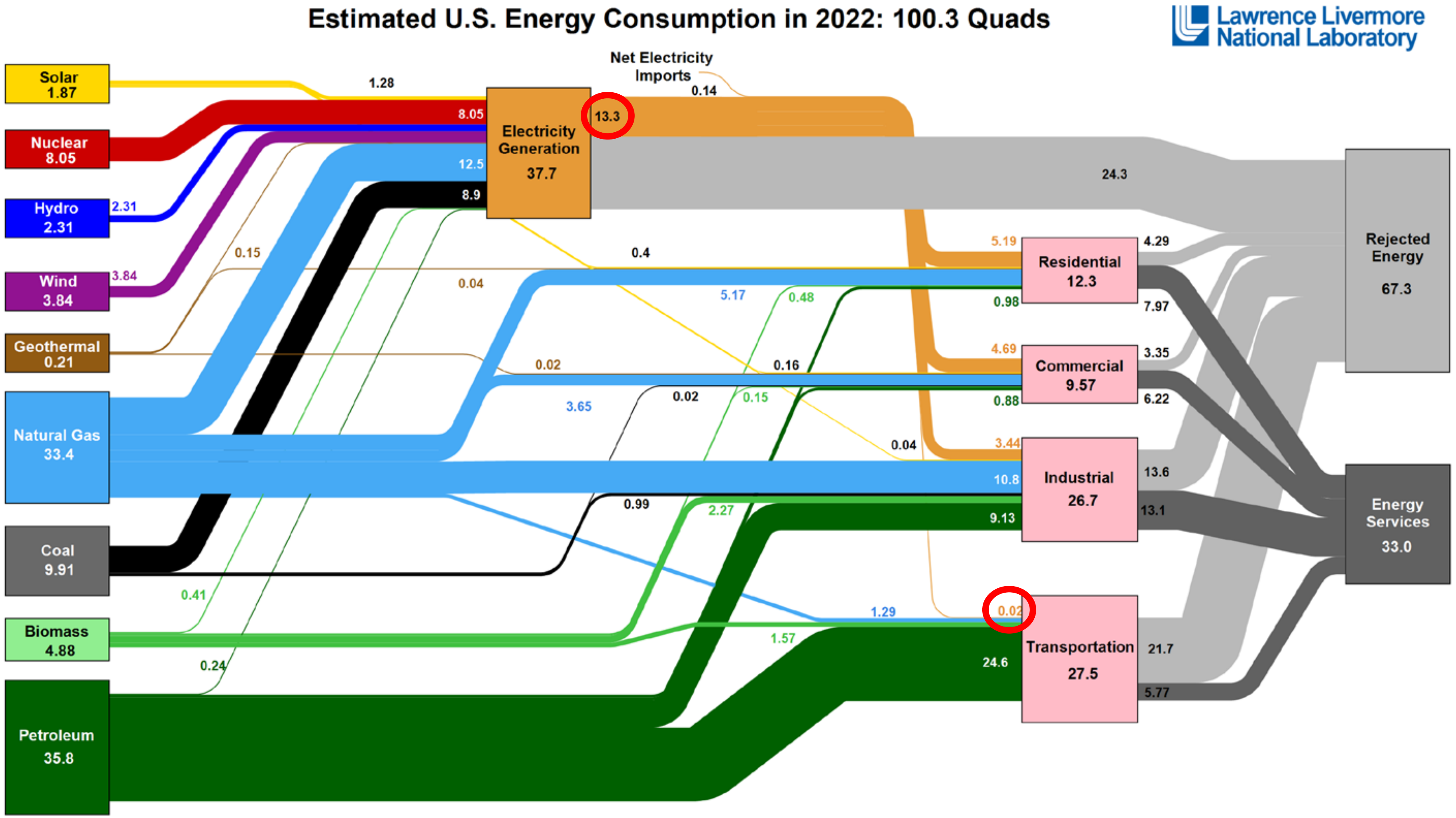
Energy Systems Integration

Grid Integration

Hybrid Systems

Security and Resilience

U.S. Transportation & Electricity Sector:
Historically Distinct & Unconnected

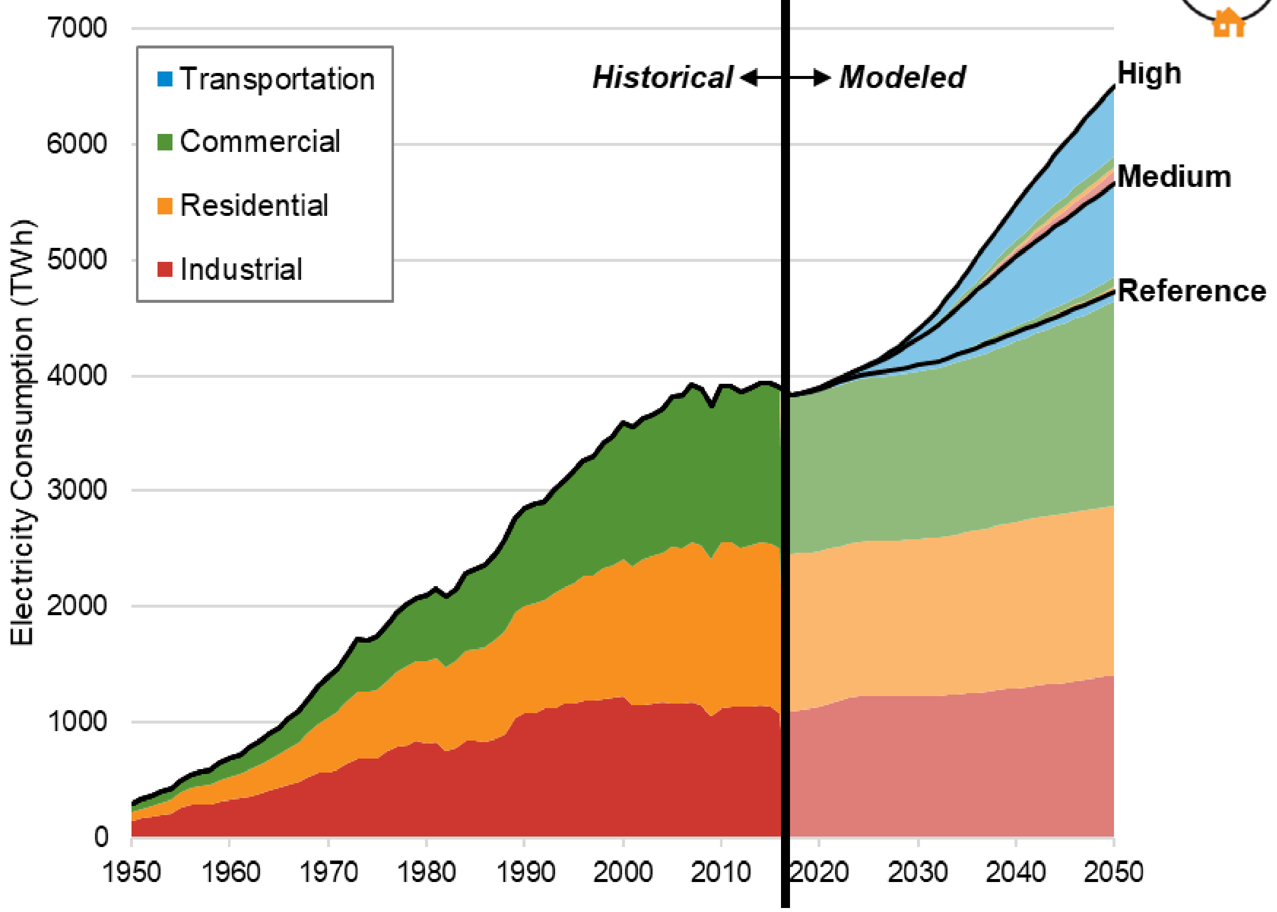


Source: LLNL July, 2023. Data is based on DOE/EIA SEDS (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 0.65% for the residential sector, 0.65% for the commercial sector, 0.49% for the industrial sector, and 0.21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

EV-Grid Integration: Why is it important?

- U.S. electricity demand has been flat for nearly 20 years.
- **Electricity demand growth expected to resume** due to data center and AI growth, domestic manufacturing, and end use electrification.
- **Transportation electrification** is expected to be a **major contributor to future electricity demand growth**.

<u>EFS High scenario, 2050</u>:
Transport share of electricity use increases from **0.2% in 2018 to 23% in 2050** (1,424 TWh/yr increase)



Source: Mai et al. (2018)

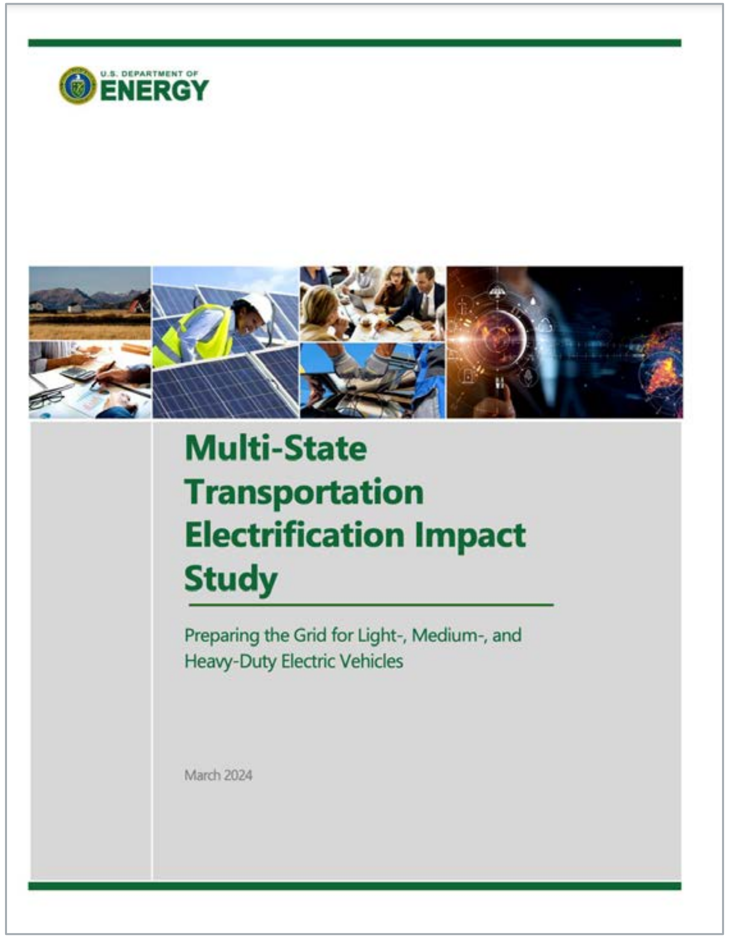
The **distribution system** plays a crucial role in supporting increasing **electrification,** whether from **transportation or other sectors**.

Utilities must anticipate when and where new loads will materialize to effectively manage load growth and avoid disruptions.

Management of EV charging can avoid overload of distribution infrastructure, mitigate equipment wear, avoid costly upgrades, and avoid voltage instability and outages, especially in high-adoption areas.

Transportation Electrification Impact Study

- The Multi-State Transportation Electrification Impact Study quantitatively assessed the **infrastructure requirements** and **distribution costs** for enabling EV charging.
- Developed approach for estimating charging infrastructure and grid upgrade costs for **all on-road electric vehicles** across five states.
- Modeled EV charging at the **site-level** (land parcels), allocating load to **substations**, **feeders**, and **transformers**.
- Assessed **managed charging strategies** for deferring grid upgrades.


U.S. DEPARTMENT OF ENERGY

Multi-State Transportation Electrification Impact Study

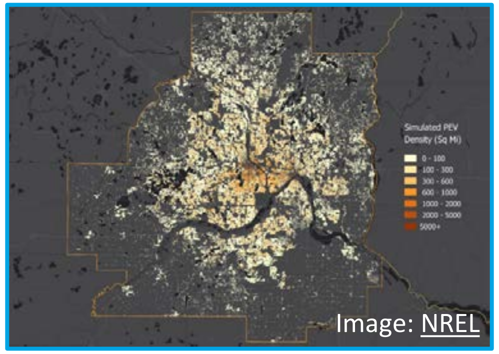
Preparing the Grid for Light-, Medium-, and Heavy-Duty Electric Vehicles

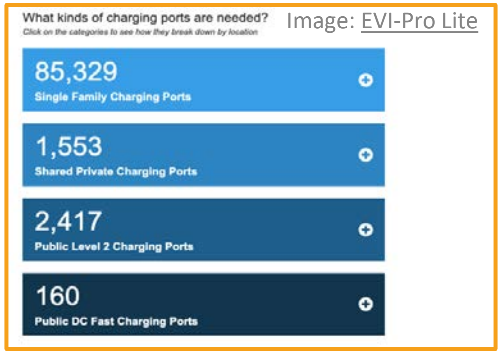
March 2024

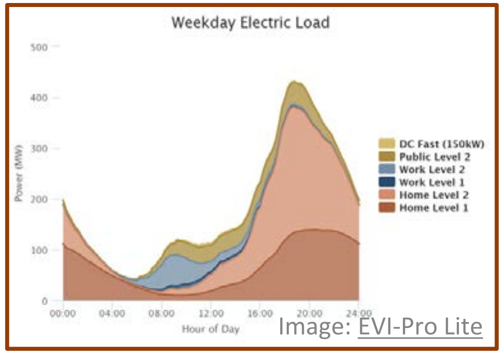
Source: Wood et al. (2024)

NREL NATIONAL RENEWABLE ENERGY LABORATORY BERKELEY LAB kevala

EV Load Forecasting







1. When/Where/Which EVs are adopted

- Which regions, communities, households are likely to adopt EVs?
- What types of EVs will be adopted?
- How quickly will EVs be adopted?

2. How EVs are operated

- How do driving requirements vary by region or household?
- Where are EVs parked during the day?
- Do EV travel patterns differ from ICE vehicles?

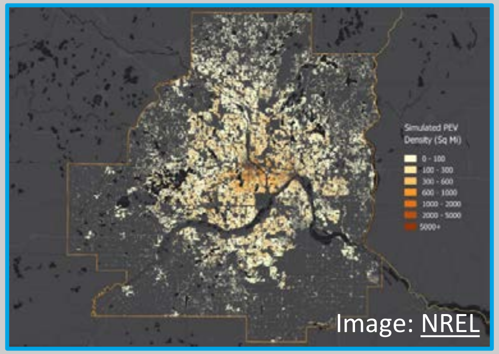
3. What charging infrastructure is required

- Can EVs charge while at home, work, or in public?
- What are the rated power levels of EV charging equipment?
- What are realistic utilization levels for public charging stations?

4. How EVs are charged

- How do EV drivers prefer to charge, and will this change over time?
- Can EVs shift (in time) or modulate their loads?
- How do EV loads respond to utility management programs (e.g., TOU)?

Step 1: Which EVs are Adopted When & Where?



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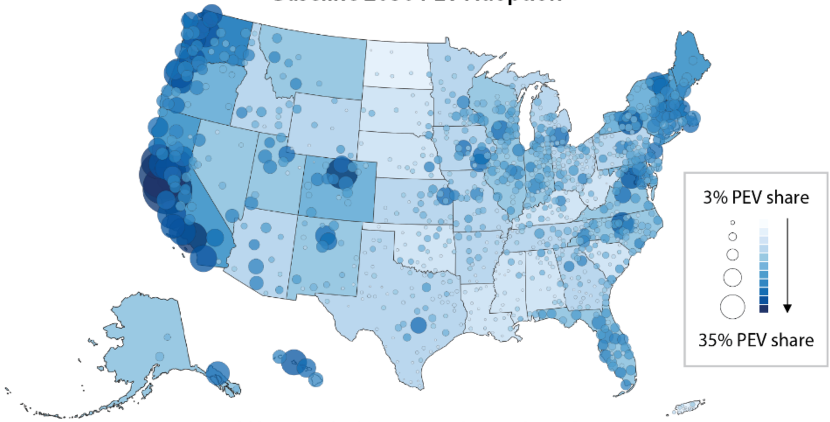
TEMPO

nrel.gov/transportation/tempo-model

TEMPO models opportunities for transportation technology/fuel adoption across various market segments and consumer groups.

Baseline 2030 PEV Adoption



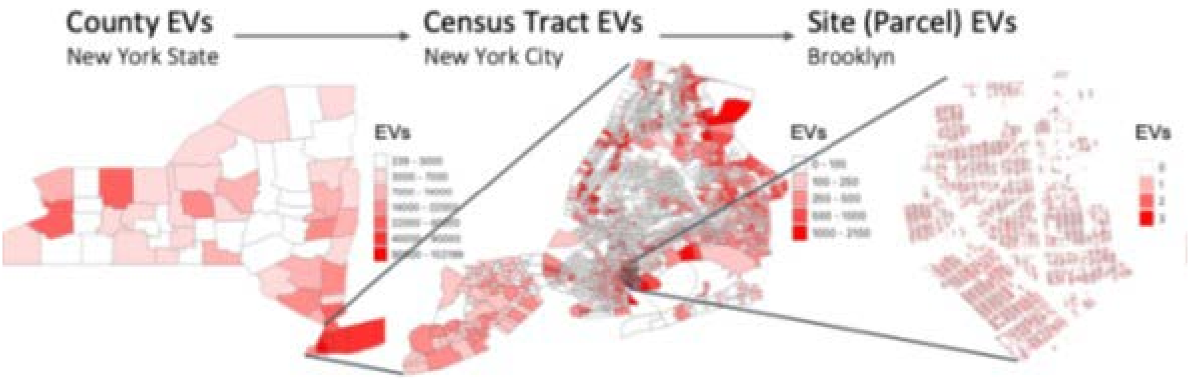
Bubble size and color represent the PEV share of LDVs per core-based statistical area (CBSA); State color represents the PEV share of LDVs in state rural areas

Source: Wood et al. (2023)

Likely Adopter Model

Disaggregates EV stock to households based on:

- Housing type
- Home ownership
- Income
- State EV policy
- Housing density class (urban, suburb, rural, etc.)



Step 2: How are EVs Driven & Where Do They Park?

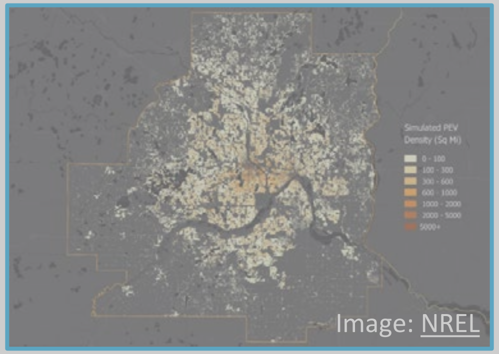


Image: NREL

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Image: Wood et al.

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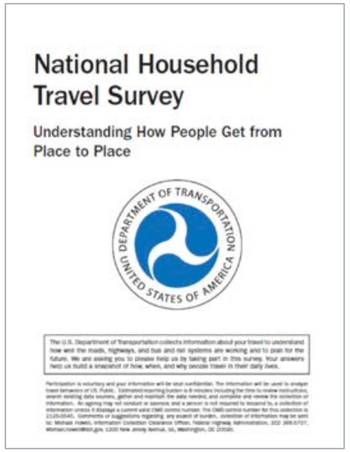
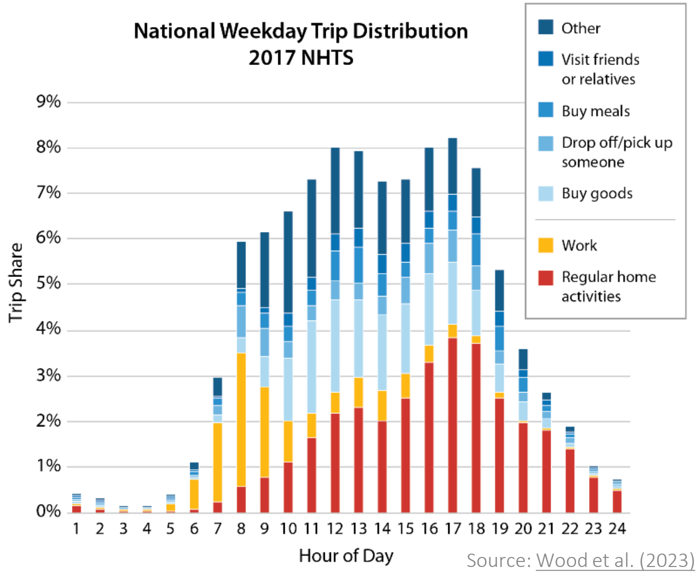
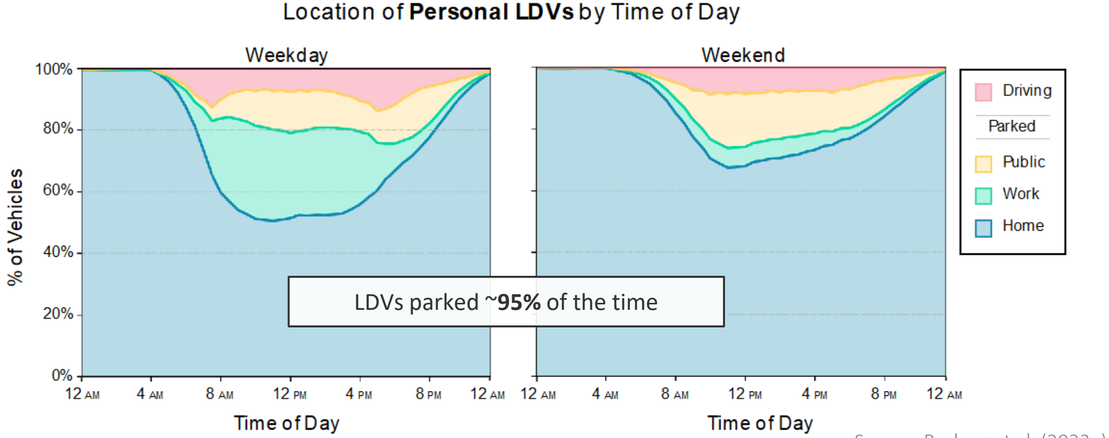


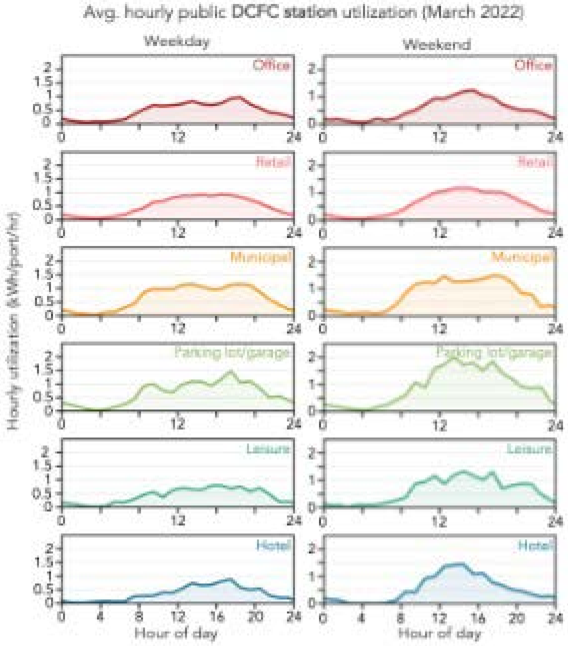


Source: Wood et al. (2023)

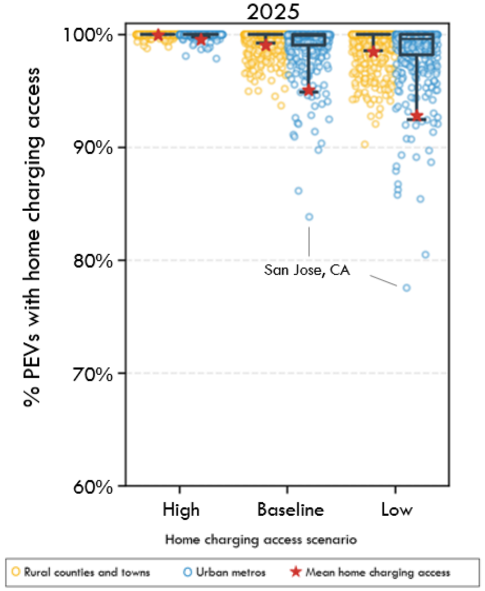


Source: Borlaug et al. (2023a)

Step 3: What Types of Chargers are Installed & Where?



Source: Borlaug et al. (2023b)



NREL EVSE Taxonomy

Access Type	Public	Private
Location Type	Home: SFH Home: MFH Neighborhood Workplace Office Retail	Recreational Healthcare School Community Center Transit Hub
EVSE Type	Level 1 Level 2 DC 50 kW	DC 150 kW DC 250 kW DC 350+ kW

Source: Wood et al. (2023)

EVI-Pro

nrel.gov/transportation/evi-pro

EVI-Pro analyzes the typical daily travel patterns of light-duty vehicles, estimate related charging demand, and design infrastructure capable of meeting the demand.

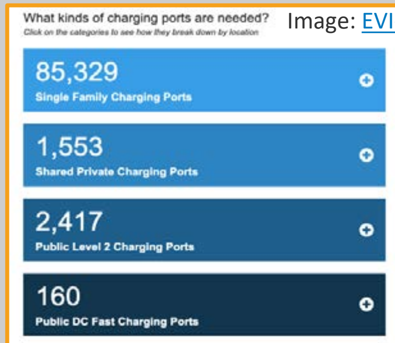


Image: EVI-Pro Lite

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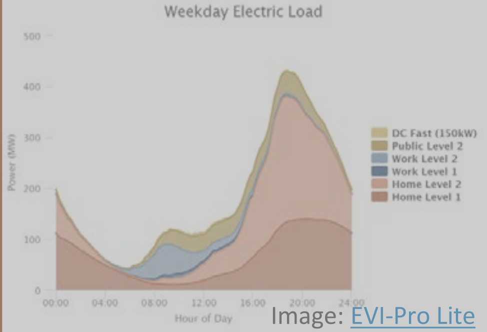

Image: EVI-Pro Lite

4. How EVs are charged

- How do EV drivers prefer to charge, and will this change over time?
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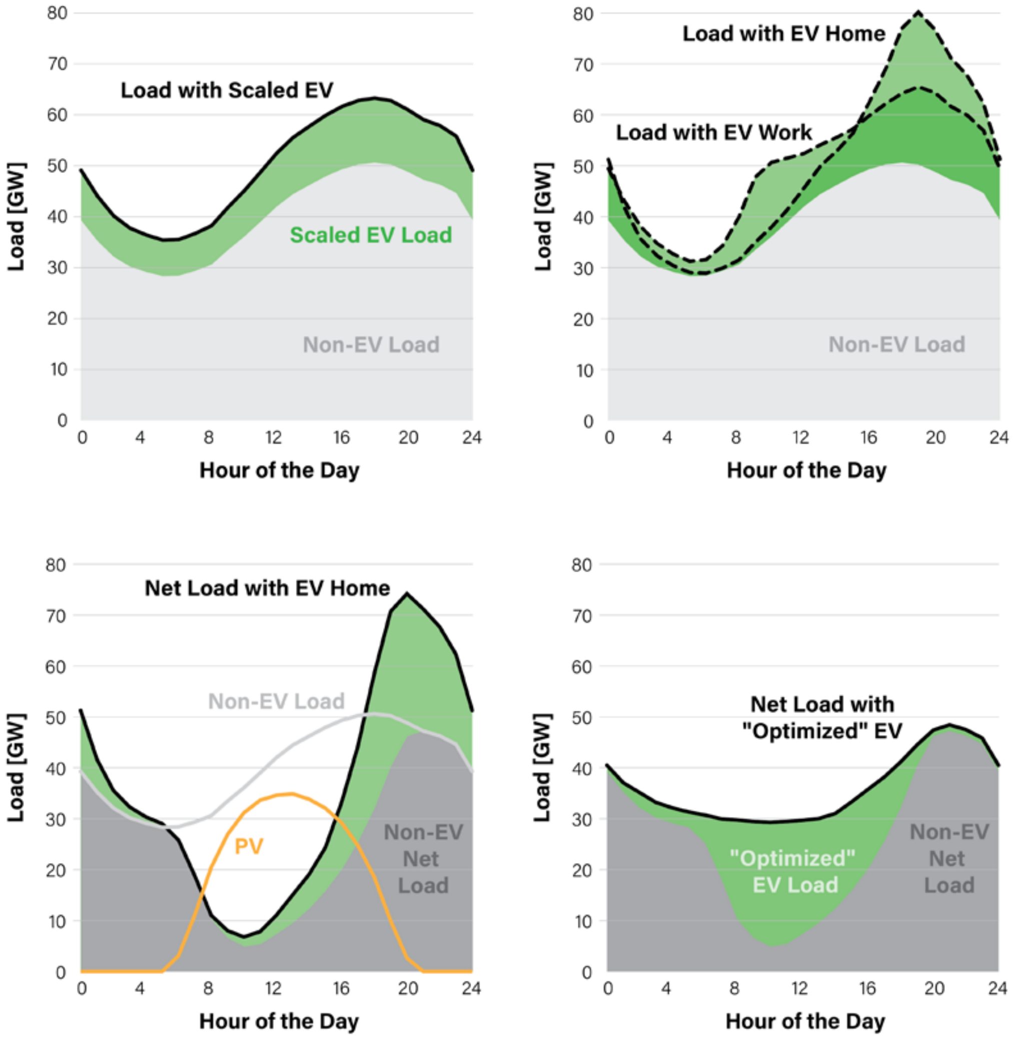
Step 4: How do EVs Charge?

a) ASSUMPTION: EV charging is often assumed to simply scale up electricity demand.

b) COMPLEXITY: Future EV charging could change the shape of demand, depending on when and where charging occurs.

c) INTEGRATION: EV charging can impact power system planning and operations, particularly with high shares of variable renewable energy.

d) FLEXIBILITY: Optimizing EV charging timing and location could add flexibility to help balance generation and demand.



Source: Muratori & Mai (2020)

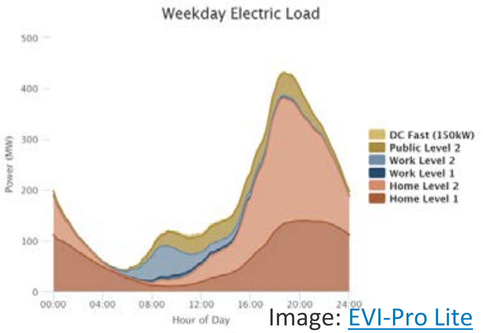


Image: EVI-Pro Lite

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References

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NREL/PR-5400-93664

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