Commercial EV Charging Infrastructure:

Modeling Concepts & Techniques

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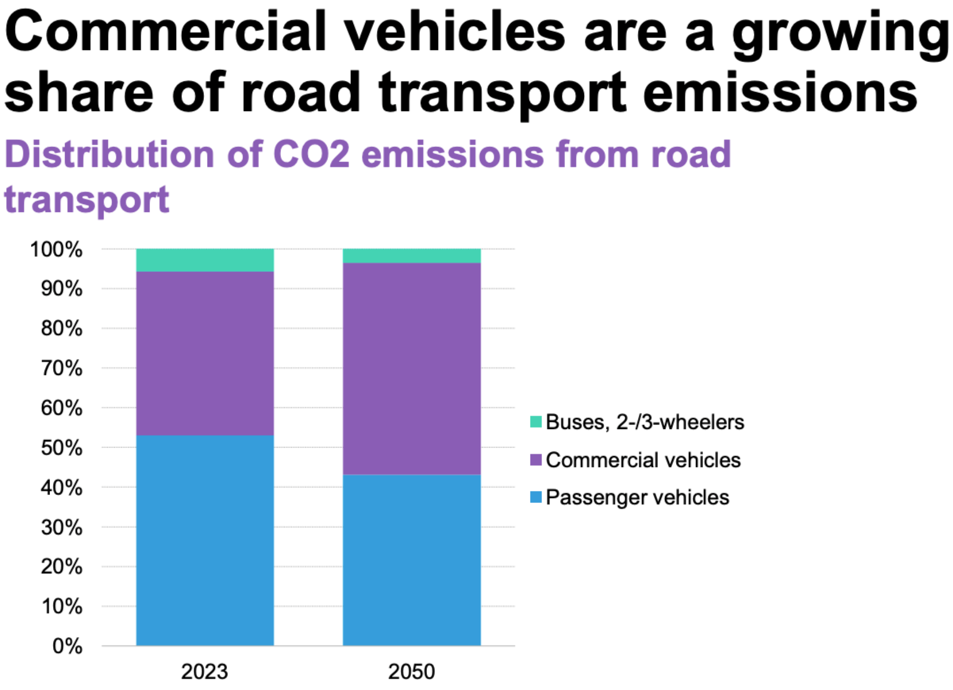
CEM EVI Workshop, EV Charging Infrastructure:
Global Modeling Approaches

Contents

EVI = Electric Vehicle (Charging) Infrastructure

Commercial Vehicles: Fastest Growing Source of Global Road Transport-Related CO_2 Emissions



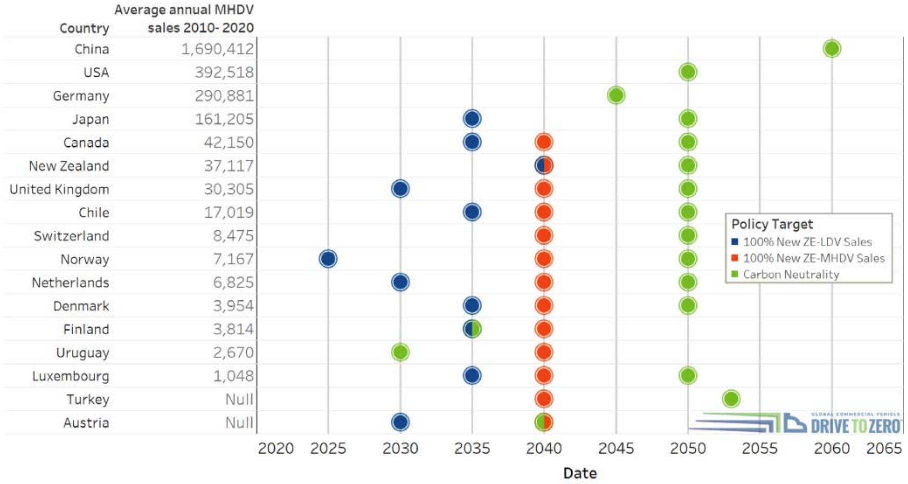
Source: BloombergNEF's 2024 Electric Vehicle Outlook Economic Transition Scenario (ETS). Note: Includes emissions from fuel combustion and upstream emissions from electricity generation. The ETS assumes no new policy intervention.

According to BloombergNEF, **CO_2 emissions from commercial vehicles will overtake passenger vehicles by 2040**, even though the commercial vehicle fleet will be <25% the size of the passenger fleet.

By 2050, the commercial vehicle fleet could grow by >33% due to increased economic activity and the growing popularity of e-commerce.

Ambitious Global Commitments for Decarbonizing Commercial Vehicles

- **>15 countries have set MHDV decarbonization targets**.
- MHDV manufacturers representing **~45% of global market share** have made some type of commitment to decarbonizing their vehicles by 2050.

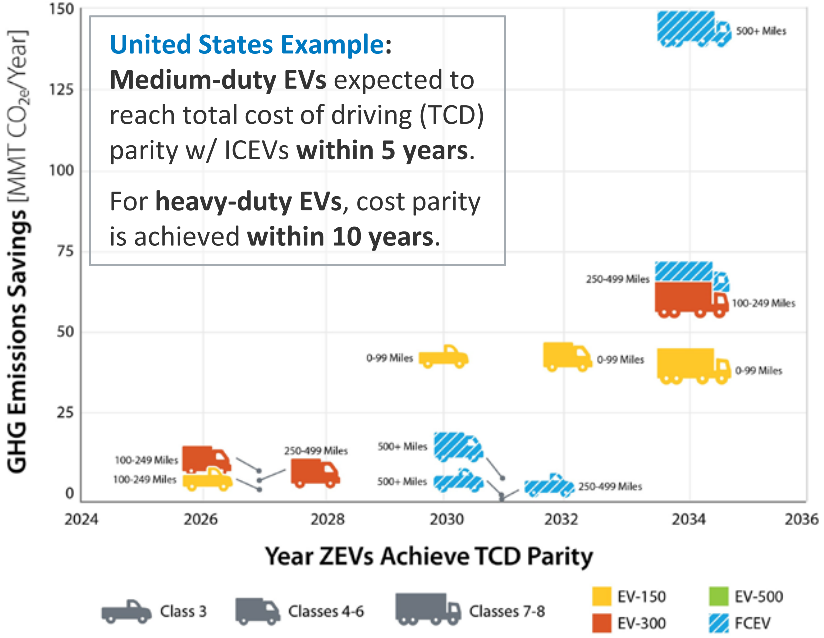


Note: Countries arranged in descending order by average annual MHDV sales from 2010 – 2020; Data unavailable for Turkey and Austria; LDV = light-duty vehicles; MHDV = Medium- and heavy-duty vehicles.

OEM	COMMITMENT	DATE
Scania	At least 90% zero-emission vehicle sales worldwide, with remainder powered by 100% fossil-free energy	2040
GM Group	100% carbon neutral in global products and operations	2040
Stellantis	70% low-emission vehicle sales in Europe, and 40% in the US	2030
Ford Group	100% fossil free new vehicle sales	2040
Daimler Group	100% carbon neutral in driving operation in Europe, North America, and Japan	2039
Toyota Group	100% CO2 neutral in life cycle by 2050	2050
Changan Automobile Group	100% electric vehicle sales	2025
Great Wall Motor Company Ltd. (GWM)	100% CO2 neutral, with interim target of 80% new energy vehicle sales by 2025	2045
Mahindra & Mahindra	100% carbon neutral in operations	2040
VW Group	100% CO2 neutral balance sheet	2050
Renault	100% CO2 neutral worldwide, with interim target of 100% CO2 neutral in Europe by 2040	2050
Nissan	100% carbon neutral across operations and product life cycle	2050
Mitsubishi	100% carbon neutral, with 50% EV sales by 2030	2050
Isuzu	100% CO2 neutral in vehicle operation and plants sheet	2050
Paccar	100% fossil free new vehicle sales	2040
Suzuki	90% reduction in CO2 emissions in driving operation	2050
Volvo Trucks Group	100% fossil free new vehicle sales	2040
CNH Industrial	100% fossil free new vehicle sales	2040
Honda	100% battery-electric and fuel cell electric vehicle sales in North America, with interim targets of 40% by 2030 and 80% by 2035	2040
Mazda	90% reduction in CO2 emissions in driving operation and energy production	2050
Hyundai Kia Automotive Group	100% CO2 neutral in all operations	2050

CALSTART (2021)

Electric Vehicles are a Promising Pathway for Decarbonizing Commercial Vehicle Operations



[Ledna et al. (2024)]

Commercial EV Advantages:

- EVs are becoming **increasingly cost competitive on an upfront basis** as battery costs continue to decline.
- EVs are more efficient than internal combustion engine vehicles (ICEVs), resulting in **significant operating cost savings**.
- EVs offer **performance advantages** that can improve safety, reliability, and driver retention.
- EVs are the **most mature technology solution** to decarbonize commercial vehicles.

TCD = total cost of driving

Commercial Vehicles are **Different from Personal Vehicles** When it Comes to EV Charging

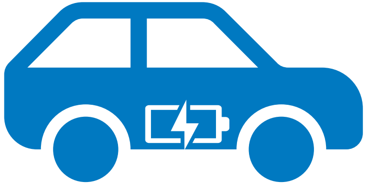
EV Charging Expectations:

More vehicles with **lower electricity demands**

Charging is **geographically distributed**

Power level: several kW to **hundreds of kW per vehicle**

Spend **95% of the time parked** (opportunity for managed charging)



Personal Vehicles

VS

Commercial Vehicles

Fewer vehicles with **higher electricity demands**

Charging is more **geographically concentrated**

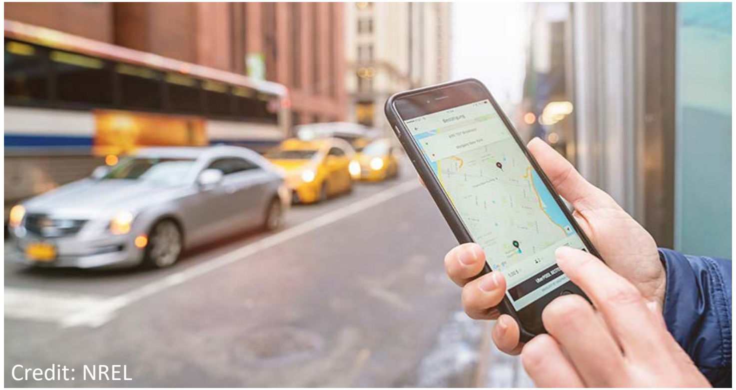
Power level: tens of kW to **1+ MW per vehicle**

Spend **less time parked**, but **more predictable operations** could enable managed charging

Personal Vehicles: Multiple Use Cases


Credit: G. Zeidler, CC BY-NC-ND

Credit: World Bank, CC BY-NC-ND


Credit: NREL

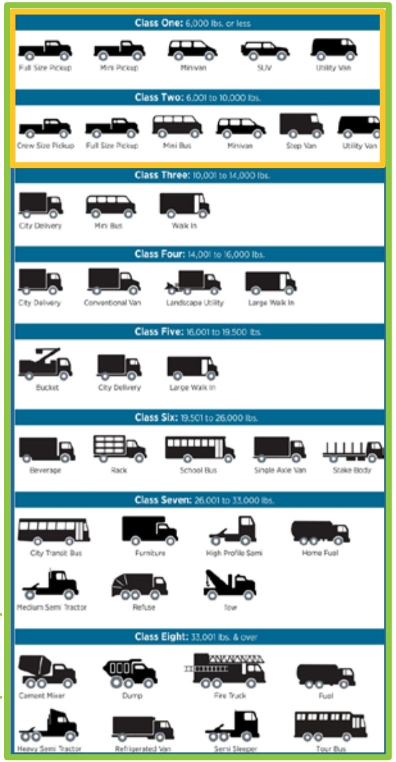

Credit: E. Jeffrey, CC BY-NC-ND

Commercial Vehicles: **Many More** Use Cases

U.S. FHWA Classifications

Personal vehicles (Class 1-2)

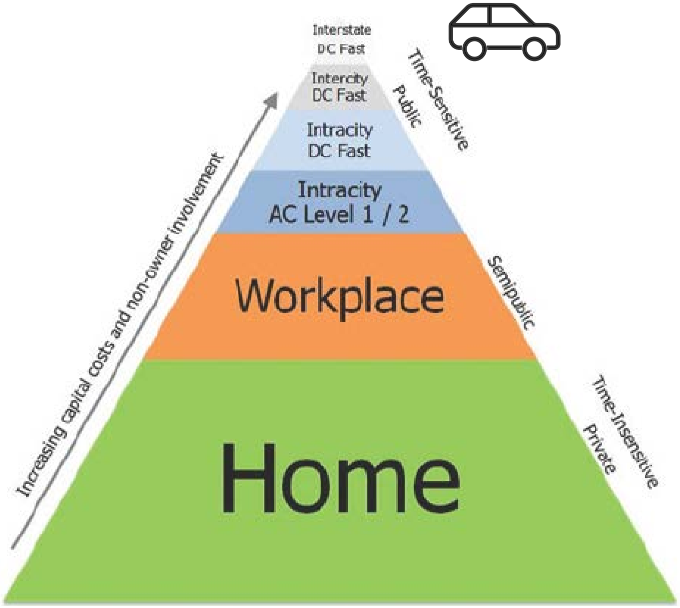
Commercial vehicles (Class 1-8)



Personal LDV Charging: "There's No Place Like Home"

Home charging is the **most convenient and preferred LDV charging option today** and represents the majority of EV electricity demand in most countries.

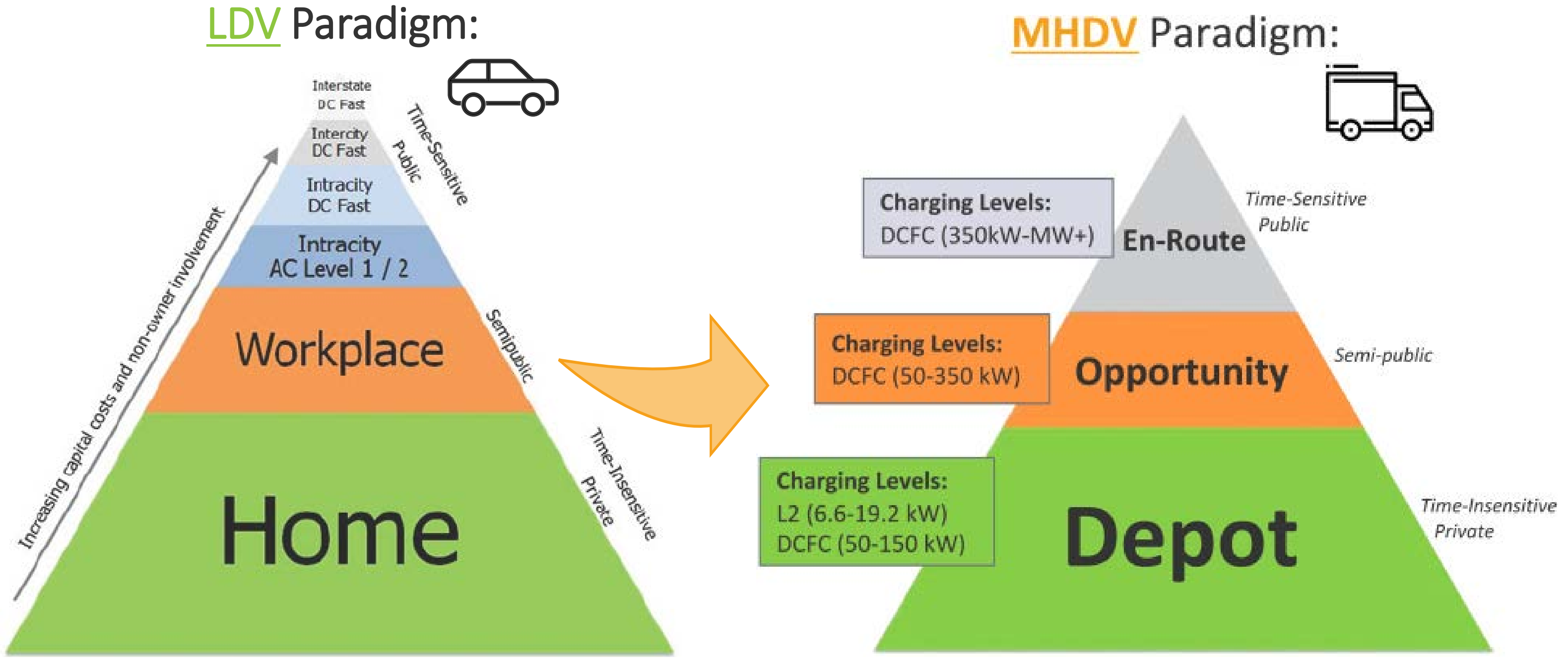
LDV Paradigm:



National Research Council (2015)

MHDV Charging: "There's No Place Like ~~Home~~ **the Depot**"

For commercial vehicles, private depot charging could play a similar role, representing the majority of EV electricity demands for limited-range operations.



National Research Council (2015)

Muratori et al. (2023)

Commercial Vehicles Have **Varying EV & Charging Requirements**

Bigger Payloads:

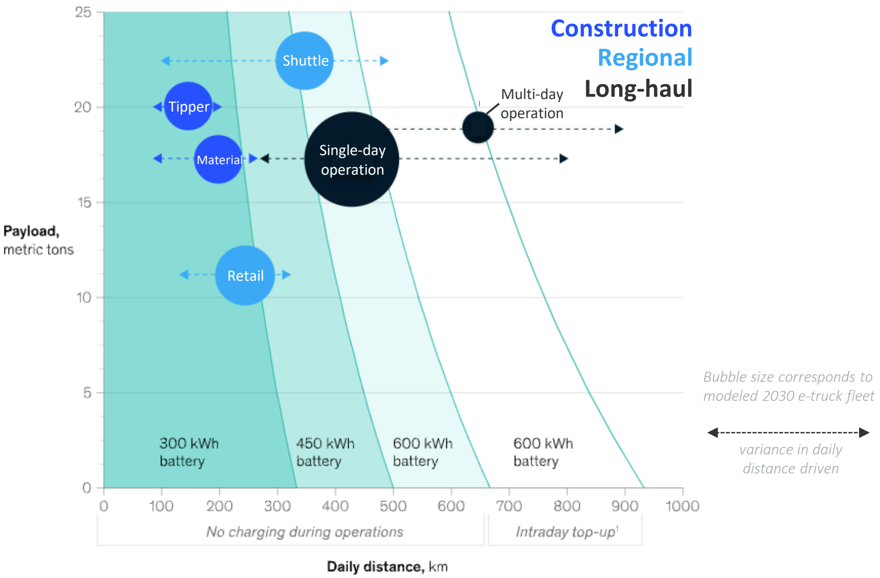
More charging or larger batteries required

Higher daily distance:

More charging or larger batteries required

Charging infrastructure, driving patterns, and battery sizes have to be optimized in concert to efficiently electrify truck operations.

2030 view, use cases



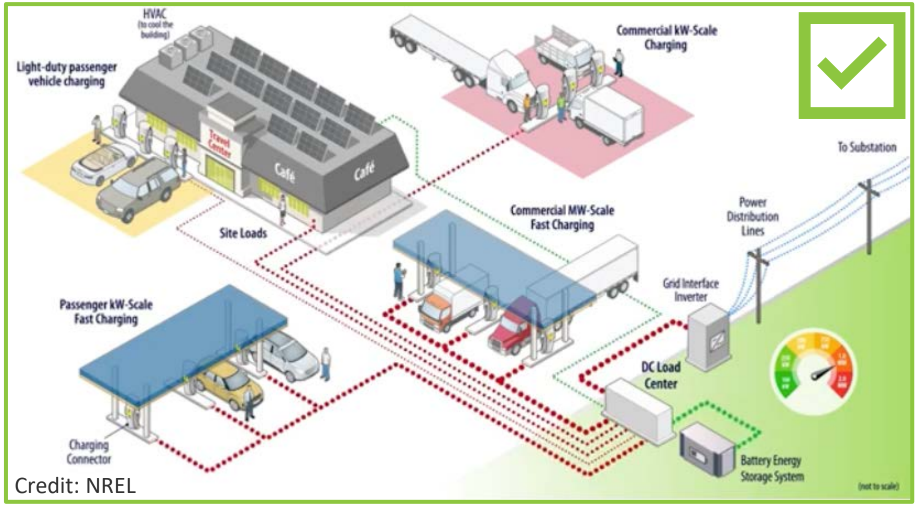
[1]Assumes charging during mandatory break of 45 minutes at 400 kW DC charger.

McKinsey & Company

adapted from:
Herlt & Hildebrandt (2024)

Port Sharing Feasibility for Commercial Vehicles Limited by **Maneuverability Constraints**

Electric semi truck blocking IONITY chargers



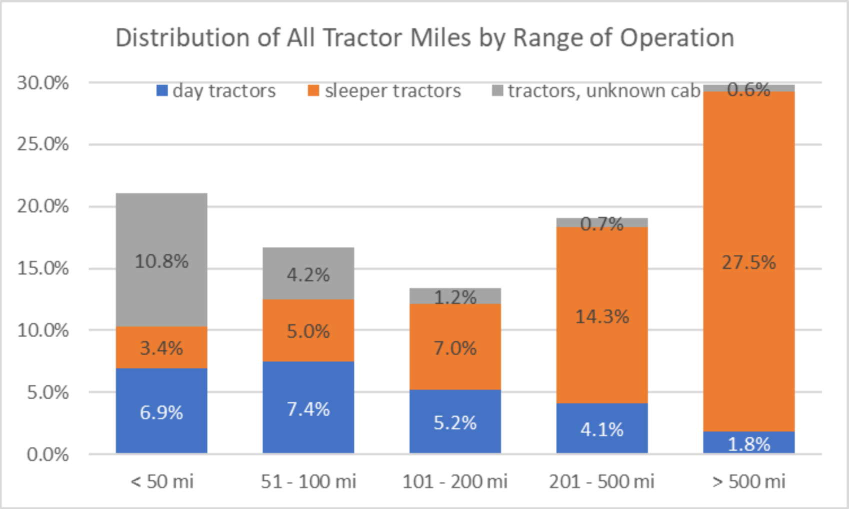
"Charging plaza of the future" can charge a variety of vehicles at different rates depending on the application.

While Smaller Commercial Vehicles May **Leverage Established Passenger Vehicle Networks**

Freight Demands May Evolve Over Time…

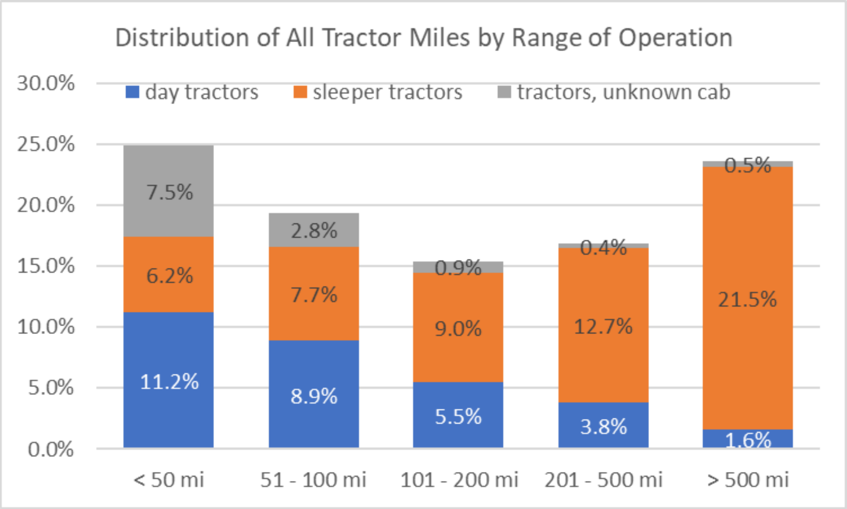
In the last 20 years, there has been a **shift toward more short-haul operations** in the U.S., driven by the growth of e-commerce, supply chain localization, and efforts to improve driver retention.

2002 (U.S.):



21% 17% 13% 19% 30%

2021 (U.S.):



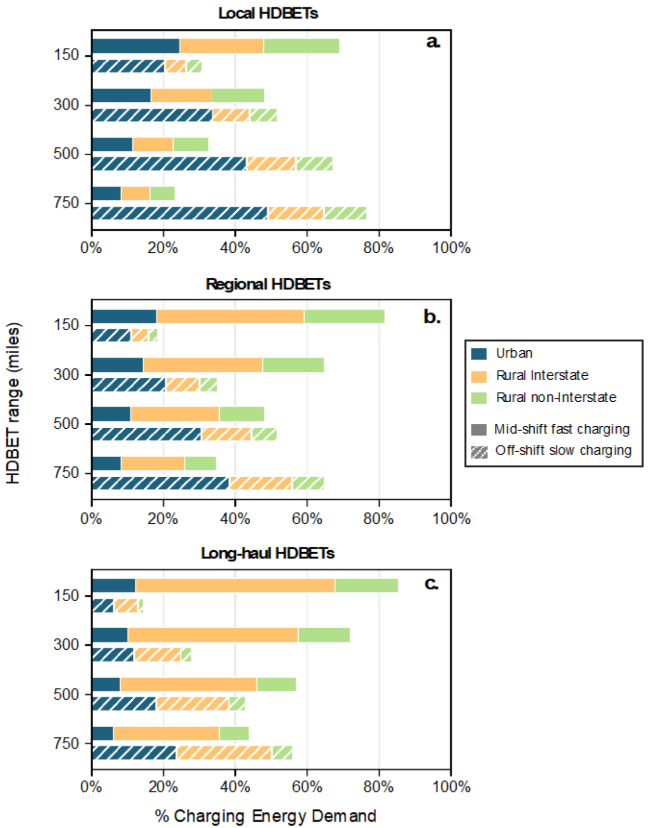
25% 19% 15% 17% 24%

+8% vs. 2002

-8% vs. 2002

U.S. DOT (2002, 2021)

…With Implications on EV Charging Demand



Borlaug et al. (2022)

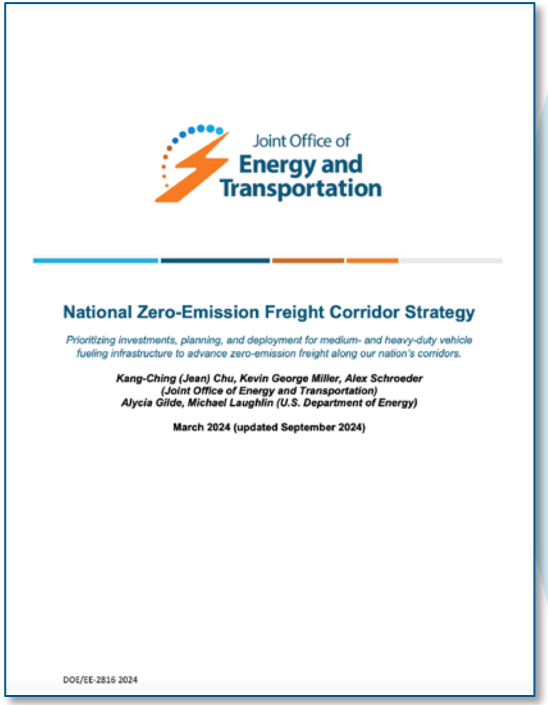
a. Local trucks primarily operate and charge in urban areas, with most charging occurring at the depot.

b. Regional trucks primarily operate between urban areas, with charging split between urban depots and rural truck stops.

c. Long-haul trucks primarily drive on rural interstates, with most charging happening at high power levels at truck stops .

Phased Rollout of Commercial Charging Infrastructure

Costly and time-consuming commercial EV charging infrastructure installations can be **phased in over time**, with an initial prioritization around favorable launch areas.


Joint Office of Energy and Transportation

National Zero-Emission Freight Corridor Strategy

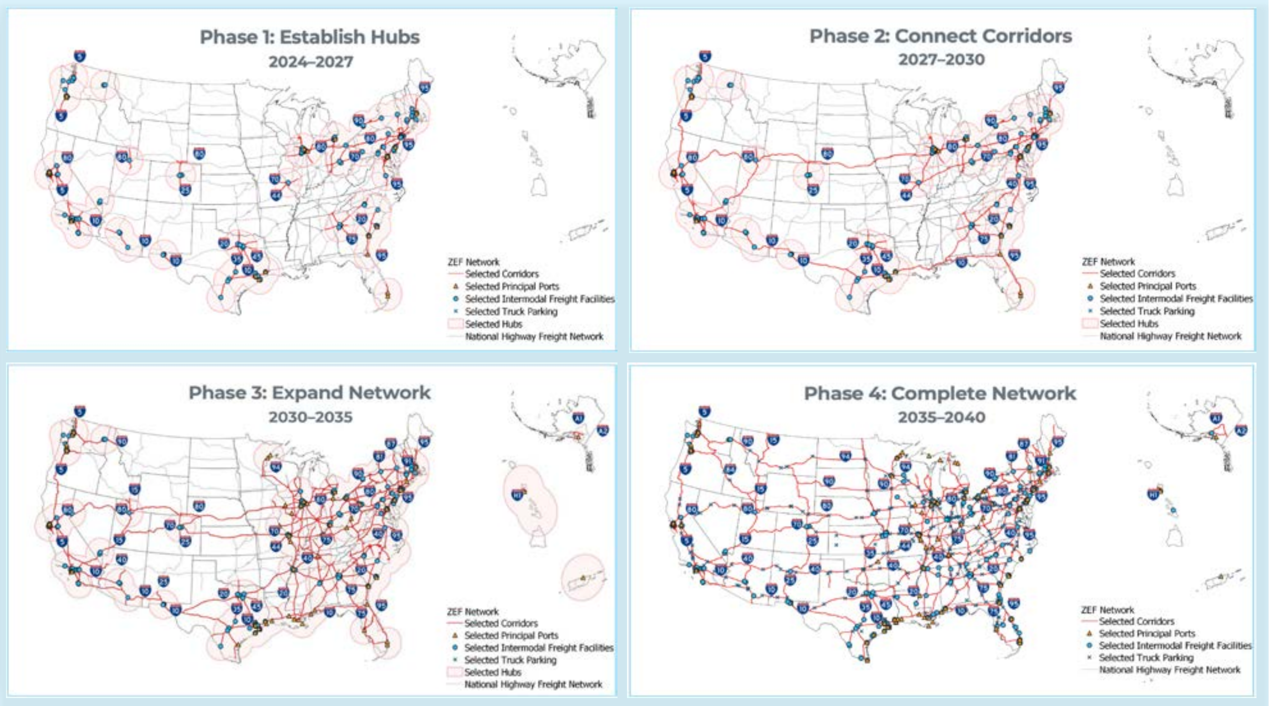
Prioritizing investments, planning, and deployment for medium- and heavy-duty vehicle fueling infrastructure to advance zero-emission freight along our nation's corridors.

Kang-Ching (Jean) Chu, Kevin George Miller, Alex Schroeder
(Joint Office of Energy and Transportation)
Alycia Gilde, Michael Laughlin (U.S. Department of Energy)

March 2024 (updated September 2024)

DOE/EE-2816 2024

Chu et al. (2024)

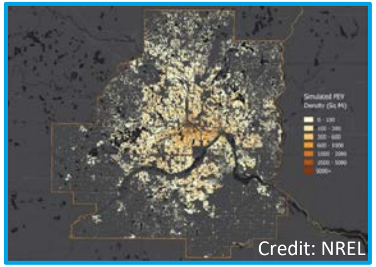


Targeted & strategic *not everything everywhere all at once*

Walkthrough:

Steps for EVI Modeling

EVI Modeling: Main Steps



Credit: NREL

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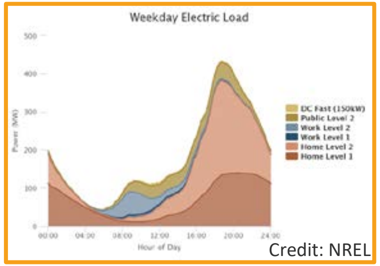
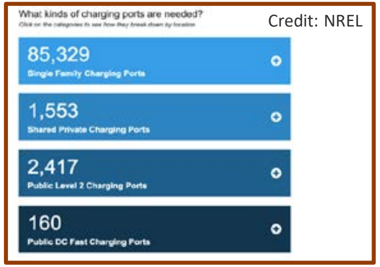


Credit: NREL



Credit: NREL

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?

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?

How EVs are charged

- Can EVs charge while at home, work, or in public?
- How do EV drivers prefer to charge, and will this change over time?
- Can EVs shift (in time) or modulate their loads?

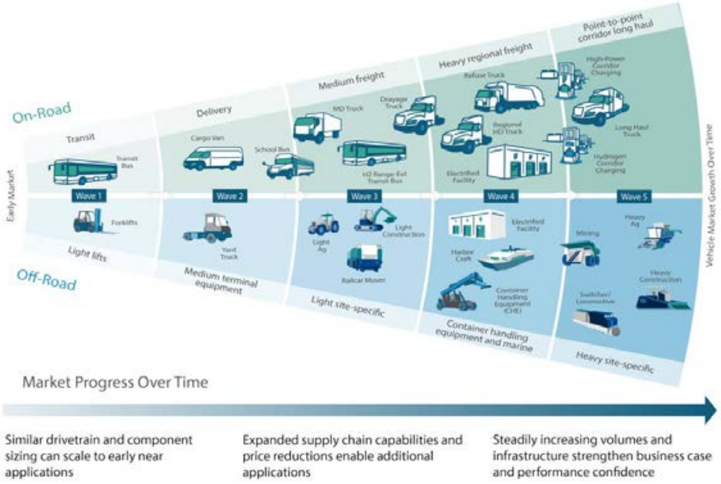
What charging infrastructure is required

- What are realistic utilization levels for charging stations?
- Which deployment strategies will EVI operators take?
- Will EVI operators employ ”idle” fees to incentivize throughput?

When/Where/Which EVs are Adopted

Basic Approaches:

- **Top-down Models**
  - **Exogenous EV stock targets** are disaggregated by region and vehicle type based on factors like consumer preferences, housing stock, land use, and local policies.
- **Bottom-up Models**
  - Technology adoption is **modeled endogenously** at the individual or fleet-level based on factors like consumer preferences, costs, and operational needs.
  - Commercial fleet decisions are more centrally controlled and driven by **total cost of ownership (TCO) and reliability** compared to household decisions.



CALSTART

Rule-of-Thumb:

Commercial vehicles with lighter payloads, predictable routes, more limited daily travel, and return-to-base operations are most likely to electrify first. Additionally, regions or vehicle segments with strong regulatory mandates, emissions reduction goals, and/or incentives are more likely to electrify early.

How EVs are Operated

1. Simple assumptions:

- Daily electricity demand (driving distance and energy consumption)
- Geographical area in which the vehicles are operated and charged

Pros:

- *Easy to implement with minimal data*
- *Rough estimate for early-stage decision making*

Cons:

- *No real-world variability or specific operational patterns*

2. Real-World Travel Data:

- Trip origin/destination times and spatial coordinates
- Trip distances
- Dwell locations (e.g., depot)

Pros:

- *More accurate representation of vehicle behavior and potential charging opportunities*

Cons:

- *High data requirements*
- *More complex to model*

3. Travel Simulations:

- Agent-based modeling
- Can generate hypothetical travel scenarios

Pros:

- *Highly detailed and customizable simulations*
- *Can model complex interactions*

Cons:

- *High data requirements*
- *Significant computational resources*

How EVs are Charged

1. Simple assumptions:

- **Shares of electricity demand** by charging type (e.g., depot, opportunity, en-route)
- **Load shapes** by charging type + load management (if any)

Pros:

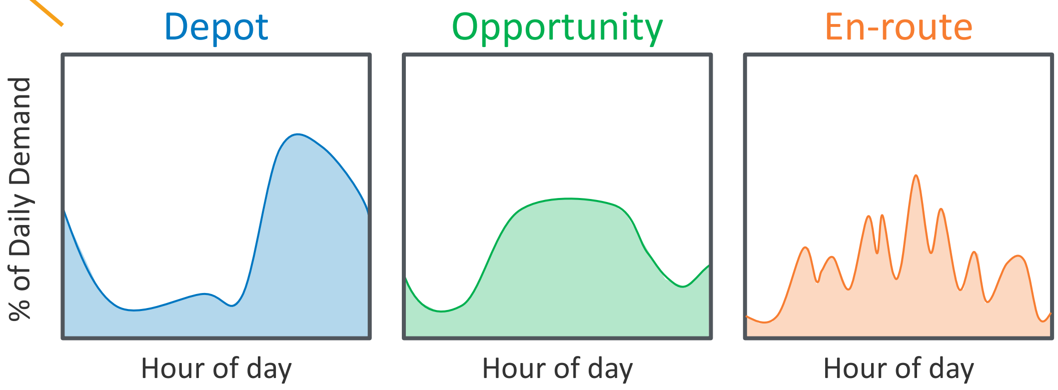
- *Easy to implement with minimal data*
- *Rough estimate for early-stage decision making*

Cons:

- *Hard to know which assumptions to use without bottom-up modeling*

Demonstrative:

MHD EV Charging Type	2030	2040	2050
Depot	80%	60%	50%
Opportunity	10%	20%	20%
En-route	10%	20%	30%



How EVs are Charged

1. Simple assumptions:

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- **Load shapes** by charging type + load management (if any)

Pros:

- *Easy to implement with minimal data*
- *Rough estimate for early-stage decision making*

Cons:

- *Hard to know which assumptions to use without bottom-up charging behavior modeling*

2. Charging Behavior Simulations:

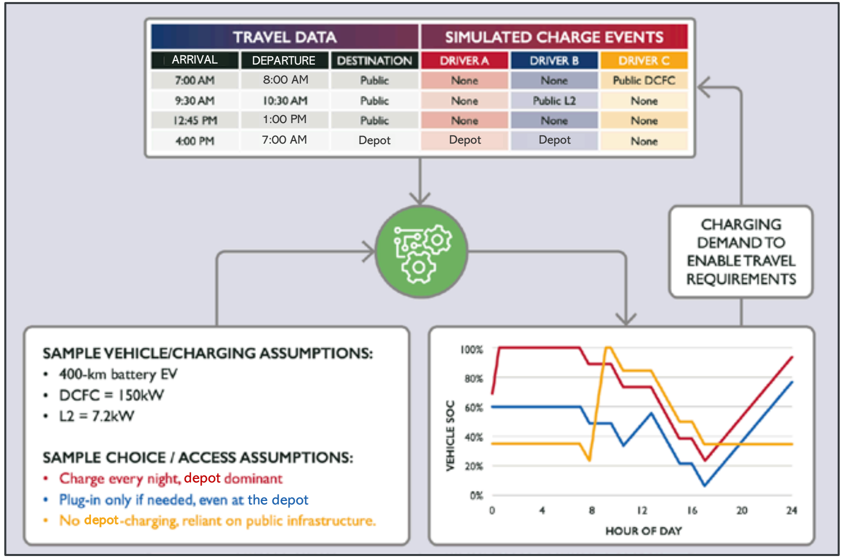
- **Bottom-up** charging behaviors that optimize for cost, convenience, etc.
- Can consider **alternative EVI access scenarios**.

Pros:

- *High precision and flexibility*
- *Can model complex interactions*

Cons:

- *Significant tuning and validation required*
- *Scalability challenges*



adapted from:

https://www.nrel.gov/docs/fy24osti/85935.pdf

What Charging Infrastructure is Required

Typically involves relationships between:

- EVI stations per rural highway mile / km
- Urban EVI stations per sq. mile / sq. km

providing ***Coverage***

simplest

- EVI ports per EV
- EVI ports per daily electricity demand
- EVI ports per peak electricity demand

advanced

providing ***Capacity***

EVI = Electric Vehicle (Charging) Infrastructure

Summary

- **Charging networks** must provide coverage and capacity.
- **Commercial vehicles** encompass a wide range of vehicle types and operations, each with unique EV charging requirements.
- **Commercial EVI deployments** can be phased in over time to reduce costs and improve network efficiency.
- **EVI Modeling** – Main Steps:

  1. *When/where/which EVs are adopted?*
  2. *How EVs are operated?*
  3. *How EVs are charged?*
  4. *What charging infrastructure is needed to meet the demand?*

Thank You!

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