Perspectives on Charging Medium- and Heavy-Duty Electric Vehicles

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Commercial Vehicles: the Largest Slice after LDV

- Medium and heavy-duty vehicles (MHDVs) are the second largest source of transportation GHG emissions (21% in the US, 31% global).

- Current MHDVs are a major source of local air pollutants that negatively impact urban air quality and human health, and disproportionately affecting disadvantaged communities located near freight corridors, ports and distribution centers.

- Zero emissions vehicles (BEV and FCEV) offer a viable decarbonization pathway.
  - While commercial deployment is still limited there are growing opportunities as technology has advanced greatly over the last decade (see Rise of EVs).

Data Source: EPA GHG Inventories
A Lot of Heterogenies within MHDV: Not all Trucks are Driven the Same – Different Charging Solutions

- ~10% of HD trucks in the United States have a primary operating range of 500 miles or more, whereas ~70% operate primarily within 100 miles.
- ~40% of energy is used by trucks that primarily operate within 100 miles.
- Recent industry trends (e.g., the rise of e-commerce and low driver retention) produced a shift towards decentralized hub-and-spoke models: 37% decrease in the average length of haul from 2000 to 2018 (not factored into Figure above).

**EV Charging Technology: a Variety of Solutions for LDV**

**LDV Paradigm:**

Charging EVs includes a lot more options than “gasoline stations”

- **Home charging** can cover most needs (~95% of trips <30 miles) but not everyone has access
- **Workplace** next biggest opportunity
- **Public charging** (L2 and DCFC) critical to build consumer confidence and enable long-distance

**Key gaps:**

- Reliable and convenient intercity charging network (few trips but confidence issue)
- Solutions for people without home charging (no single answer)
- Providing convenient access to underserved communities
- Reducing costs and grid integration

EV Charging Technology: a Variety of Solutions for MHDV

**MHDV Paradigm:**

Charging EVs includes a lot more options than “gasoline stations”

- **Depot charging** can cover most needs (~87% of U.S. MHDVs primary operating range <200 miles) but requires on-site charging for all vehicles
- **Opportunity charging** (e.g., while loading/unloading or on break) could provide additional opportunity
- Public en-route charging (DCFC, MW+) as a safety net and for long-haul applications

**Key gaps:**

- Depot-charging solutions for all fleets/drivers (no single answer)
- Develop and demonstrate reliable opportunity charging solutions
- Intercity MW+ charging network (critical for some regional and most long-haul trucks)
- Reducing costs and grid integration

**Charging Levels:**

- **Depot:** L2 (6.6-19.2 kW) DCFC (50-150 kW)
- **Opportunity:** DCFC (50-350 kW)
- **En-Route:** DCFC (350kW-MW+)
Depot Charging Critical for MHDV Electrification

ICCT, Sep. 2021

- Estimates **2 million overnight private chargers** (e.g., depot) needed for **2.4 million U.S. ZEV tractors by 2050** (~77% of all chargers)

Atlas Public Policy, Nov. 2021

- Projects **most chargers will be needed at depots** – 500k by 2030, and that 75%-90% of MHDEV charging will be at depots.

Infrastructure Needed for 100% U.S. ZEV tractor sales from 2040

Cumulative ports & committed investment needed to support electrification of depot-charging

Data Source: ICCT, 2021

Data Source: Atlas, 2021
Heavy-duty truck electrification and the impacts of depot charging on electricity distribution systems

Brennan Borlaug¹, Matteo Muratori¹,², Madeline Gilleran¹, David Woody², William Muston², Thomas Canada³, Andrew Ingram³, Hal Gresham³ and Charlie McQueen³
Short-Haul Trucks: Limited Daily VMT and Abundant Charging Opportunity

- Based on real-world data: a lot of heavy trucks drive fairly low daily mileage and offer multiple charging options.

- These fleets have **ample opportunity for depot charging**, averaging 14 hours of downtime per day.

- **Depot charging provides load flexibility** (from long predictable dwell times), enabling peak demand to be reduced through **managed charging strategies**.
We found that 16, 23 and 103kW per vehicle charging power levels were sufficient for electric trucks to fully recharge when off shift, all much lower than is generally assumed.

- Depot-level peak < than sum of individual vehicles charging due to the asynchronous charging

**Financial benefit to low-power charging:**

- For utilities, it produces lower peak demand and a smooth and predictable load profile
- **Fleet managers** save on the capital costs of EVSE (purchase and installation of 50 kW 62–81% cheaper than 350kW).
- In addition, fleets can save on electricity costs from reduced demand charges, if present.
En-Route Corridor Charging

• Long-haul (and some regional) trucks will require **mid-shift en-route “fast”** (e.g., MW+) **charging** to remain on schedule.

• **En-route “truck stop” charging demand will be heterogenous** and dependent on:
  - **Vehicle design** (esp. battery cost and performance) and regional adoption
  - Possible **logistics** changes (how trucks are operated, shipping routes)
  - Size & **design** of en-route charging network (including distributed generation and storage)
  - **Regulation**: hours of service rules and role of **automation**
Higher energy demands increase the likelihood for upgrades further upstream in the distribution system which are more expensive and take longer to complete.

**Approach:** Review of 10 public data and literature sources, supplemented by internal expert elicitation by industry co-authors.

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**Table 1 | Summary of electricity distribution system upgrades for depot charging**

<table>
<thead>
<tr>
<th>Component category</th>
<th>Upgrade</th>
<th>Typical cause for upgrade</th>
<th>Typical cost*</th>
<th>Typical timeline (month)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer on-site</td>
<td>50 kW DCFC EVSE</td>
<td>EVSE addition</td>
<td>Procurement, US$20,000-36,000 per plug; installation, US$10,000-46,000 per plug^b</td>
<td>3-10</td>
</tr>
<tr>
<td>150 kW DCFC EVSE</td>
<td></td>
<td></td>
<td>Procurement, US$75,000-100,000 per plug; installation, US$19,000-48,000 per plug^a</td>
<td></td>
</tr>
<tr>
<td>350 kW DCFC EVSE</td>
<td></td>
<td></td>
<td>Procurement, US$128,000-150,000 per plug; installation, US$26,000-66,000 per plug^c</td>
<td></td>
</tr>
<tr>
<td>Install separate meter</td>
<td></td>
<td>Decision to separately meter</td>
<td>US$1,200-5,000</td>
<td></td>
</tr>
<tr>
<td>Utility on-site</td>
<td>Install distribution transformer</td>
<td>200+ kW load</td>
<td>Procurement, US$12,000-175,000</td>
<td>3-8</td>
</tr>
<tr>
<td>Distribution feeder</td>
<td>Install/upgrade feeder circuit</td>
<td>5+ MW load^c</td>
<td>US$2-12 million^d</td>
<td>3-12*</td>
</tr>
<tr>
<td>Distribution substation</td>
<td>Add feeder breaker</td>
<td>5+ MW load^c</td>
<td>-$US400,000</td>
<td>6-12^</td>
</tr>
<tr>
<td></td>
<td>Substation upgrade</td>
<td>3-10+ MW load^d</td>
<td>US$3-5 million</td>
<td>12-18</td>
</tr>
<tr>
<td></td>
<td>New substation installation</td>
<td>3-10+ MW load^d</td>
<td>US$4-35 million</td>
<td>24-48^h</td>
</tr>
</tbody>
</table>

*Cost and timeline ranges include procurement, engineering, design, scheduling, permitting and construction and installation; estimates are project-specific and vary greatly. *Costs reflective of 2019 and expected to continue to fall in future years; EVSE installation includes upgrading or installing service conductors and load centers; per-unit installation costs are reduced as the number of installed units increase. *Feeder extensions or upgrades (including new feeder breakers) are typically required for new loads >5 MW, especially for voltages <20 kV; new loads >12 MW may require a dedicated feeder. *Feeder extensions or upgrades tend to be more expensive in urban areas than in rural areas. *Timeline for feeder extensions includes jurisdictional permitting for construction, obtaining easements and right-of-way, and procurement lead times. *Timeline for adding a new feeder breaker depends on substation layout and the time required to receive clearance for construction. *The decision to upgrade an existing substation versus to build a new one is largely dependent on the layout of the existing substation and whether there is sufficient room for expansion. *Additional time may be required for regulatory approval for the transmission line construction. DCFC, direct current fast charging.
Grid Integration is more than Impacts: Opportunity for Managed Charging

- Many MHDVs have duty cycles conducive to managed charging and/or bi-directional energy transfer (V2G).
- Depot charging loads are more flexible than en-route charging, providing opportunities for managed charging.

Value of Electric Vehicle Managed Charging

- Reduce Bulk Power Systems Investment Costs: 20–1350 $/EV/year
- Reduce Bulk Power Systems Operating Costs: 15–360 $/EV/year
- Reduce Renewable Energy Curtailment: 23–2400 kWh/EV/year
- Reduce Distribution Systems Investment Costs: 5–1090 $/EV/year
- Increase Distribution Systems EV Hosting Capacity: 30–450%

Emerging topic: Vehicle electrification is rapidly transforming the transportation-energy landscape across multiple modes and with far-reaching cross-sectoral implications.

Electric Medium Heavy-Duty Vehicles offer major emissions benefits (air quality) and if financial tipping point is reached adoption could scale up rapidly. The time to prepare is now!

Need:

Demonstration to assess transition obstacles and build knowledge on charging needs, costs, effective practices and grid integration (international transfer)

Nuanced demand-side modeling to assess EV charging needs (infrastructure) and flexibility: when and where EV charging occurs will be as important as how much electricity is needed

EV integration opportunities: synergistic improvement of the efficiency and economics of electromobility and evolving electric systems (lower charging costs and support the grid)
References


Questions?

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Supplemental
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- Medium and heavy-duty vehicles (MHDVs) are the second largest source of global transport GHG emissions (heavy trucks ~25% of total).
- Current MHDVs are a major source of local air pollutants that negatively impact urban air quality and human health, and disproportionately affecting disadvantaged communities located near freight corridors, ports and distribution centers.
- Zero emissions vehicles (BEV and FCEV) offer a viable decarbonization pathway.
  - While commercial deployment is still limited there are growing opportunities as technology has advanced greatly over the last decade (see *Rise of EVs*).
Recent policy momentum for heavy-duty truck electrification:

- In June 2020, CARB adopted Advanced Clean Trucks (ACT) regulation requiring the sale of zero-emission heavy-duty trucks starting in 2024 and requiring 40% ZEV truck tractor sales by 20356.
  - This year (2021), New Jersey announced plans to become the first state to adopt CA’s mandate

- In June 2020, electric utilities in California, Washington, and Oregon provide a roadmap for freight and delivery EV charging infrastructure along I-5 and adjoining highways7.

- In July 2020, Governors from 15 states (+ Washington, D.C.) signed joint MOU committing to 100% of M/HDV sales be ZEVs by 2050 with an interim target of 30% ZEV sales by 20308.

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Insight 2: Multiple Charging Options
Managed Charging Greatly Reduces Peak

- With unmanaged charging ("100 kW immediate"), peak demand coincides with the typical system-level peak period (5 pm – 9 pm)
- Through scheduled charging ("100 kW delayed"), peak demand may be shifted 8-12 hours throughout the course of the night
- With intelligent modulation ("Constant min. power"), peak demand can be greatly reduced.
- All charging loads (15-mins) freely available to download [LINK]
Basic diagram of **secondary electrical distribution system**. Larger commercial customers may elect to own their own transformer and connect directly to the medium-voltage **primary network**, in which case the meter would be located on the opposite side of the distribution transformer.
Concluding Remarks

Emerging topic: Vehicle electrification is rapidly transforming the transportation-energy landscape across multiple modes and with cross-sectoral impacts.

Need: More nuanced demand-side modeling to assess EV charging needs and flexibility

EV integration opportunities: solutions for synergistic improvement of the efficiency and economics of electromobility and evolving electric systems

*When and where EV charging occurs will be as important as how much electricity is needed*

EVs can support the grid in multiple ways providing values for different stakeholders, including non-EV owners.