Perspectives on Charging Medium- and Heavy-Duty Electric Vehicles

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IEA Public Webinar on Public Charging Infrastructure Deployment Strategies and Business Models

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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% globally).

- 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*).

2019 U.S. GHG Emissions

- Transportation (33%)
- Electric Power (24%)
- Industry (21%)
- Agriculture (9%)
- Buildings (13%)
- Medium and Heavy Vehicles (21%)
- Light Trucks (30%)
- Off Road (9%)
- Rail (2%)
- Water (3%)
- Aviation (11%)
- Other (Pipeline/Military/Lubricants) (3%)

Aviation and water include emissions from international bunker fuels. Fractions may not add up to 100% due to rounding.

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)
- **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 MHDVs

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)
- **Opportunity charging** (e.g., while loading/unloading or on break) could provide next biggest 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
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

Data Source: ICCT, 2021

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

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

Brennan Borlaug, Matteo Muratori, Madeline Gilleran, David Woody, William Muston, Thomas Canada, Andrew Ingram, Hal Gresham and Charlie McQueen
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.
Depot Charging Requirements

• 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.
• 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:
  
  o **Vehicle design** (esp. battery cost and performance) and regional adoption
  
  o Possible **logistics** changes (how trucks are operated, shipping routes)
  
  o **Size & design** of en-route charging network (including distributed generation and storage)
  
  o **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</td>
<td>3-10</td>
</tr>
<tr>
<td></td>
<td>150 kW DCFC EVSE</td>
<td></td>
<td>Procurement, US$75,000-100,000 per plug; installation, US$19,000-48,000 per plug</td>
<td></td>
</tr>
<tr>
<td></td>
<td>350 kW DCFC EVSE</td>
<td></td>
<td>Procurement, US$128,000-150,000 per plug; installation, US$26,000-66,000 per plug</td>
<td></td>
</tr>
<tr>
<td>Install separate meter</td>
<td>Decision to separately meter</td>
<td></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</td>
<td>US$2-12 million</td>
<td>3-12</td>
</tr>
<tr>
<td>Distribution substation</td>
<td>Add feeder breaker</td>
<td>5+ MW load</td>
<td>-US$400,000</td>
<td>6-12</td>
</tr>
<tr>
<td></td>
<td>Substation upgrade</td>
<td>3-10+ MW load</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</td>
<td>US$4-35 million</td>
<td>24-48</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 reflects 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. Feeher 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%
Concluding Remarks

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)


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Supplemental
Commercial Vehicles: the Largest Slice after LDV

- 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*).

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Global CO₂ Emissions from Transport by Subsector

Data Source: IEA, 2021
Current Momentum for Heavy-Duty Electrification

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 2035. 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 highways.

- 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 2030.

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7 West Coast Clean Transit Corridor Initiative Study, June 17, 2020, [https://www.westcoastcleantransit.com/resources/WestCoastCleanTransitNewsRelease-Website.pdf](https://www.westcoastcleantransit.com/resources/WestCoastCleanTransitNewsRelease-Website.pdf)

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.
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.

Smart electric vehicle-grid integration can provide flexibility – the ability of a power system to respond to change in demand and supply – by charging and discharging vehicle batteries to support grid planning and operations over multiple time-scales.

<table>
<thead>
<tr>
<th>Power System Application</th>
<th>Time Scale</th>
<th>Vehicle-Grid Integration Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation Capacity and Transmission/Distribution Planning</td>
<td>Multi-year</td>
<td>Ability to reduce peak load and capacity requirements and defer distribution systems upgrades if reliable EV charging flexibility is available</td>
</tr>
<tr>
<td>Resilience To Extreme Events</td>
<td>Years (planning), hours (real-time response)</td>
<td>Load response to natural events (heat waves, tornados) or human-driven disasters, load postponement over days, and support microgrid management and grid restoration (V2G)</td>
</tr>
<tr>
<td>Seasonal Planning (Hydro/Long-Term Storage Dispatch)</td>
<td>Months</td>
<td>No role for EVs</td>
</tr>
<tr>
<td>Commitment and Dispatch Decisions</td>
<td>Days to Hours and Sub-Hours</td>
<td>Leverage EV charging flexibility to support supply dispatch and load-supply alignment (tariff management), variable renewables integration, operating reserves, energy arbitrage (V2G)</td>
</tr>
<tr>
<td>Balancing and Power Quality</td>
<td>Seconds to sub-seconds</td>
<td>Provide voltage/frequency regulation and support distribution system operations</td>
</tr>
<tr>
<td>Support End Consumers</td>
<td>Years (planning), hours (real-time response)</td>
<td>Tariff management (e.g., mitigate retail demand charges), complement other distributed energy resources (smart load, generation and storage), and minimize equipment aging/upgrades</td>
</tr>
</tbody>
</table>