Infrastructure to support a 100% zero-emission tractor-trailer fleet in the United States by 2040

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Felipe Rodriguez, Program Lead, Heavy-Duty Vehicles

WEBINAR
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Introduction
More Intense Climate Change Events

2021 Louisiana Floods

Source: https://www.weather.gov/safety/flood-states-la

2021 Dixie Fire

Source: https://www.nps.gov/lavo/learn/news/juniper-lake-cabins-destroyed-dixie.htm

20-Year Ongoing West Coast Drought

Source: https://droughtmonitor.unl.edu/CurrentMap.aspx

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

Author:
Brad Rippey
U.S. Department of Agriculture
Climate Impacts of Transportation

- Transport releases more GHGs than any other source in the US
- Tractor-trailers are ~13% of the MHD fleet
- Tractor trailers produce ~60% of MHD emissions

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Five Key Actions to Accelerate Zero Emission Trucks and Buses

- Phase-in targets
- Zero Emission Performance Requirements
- Fiscal incentives
- Fueling and charging infrastructure
- Purchase requirements
Approach and Key Findings
What’s the scale of the rollout until 2050?

- 2.4 million zero-emission tractor-trailers on the road
- 2.5 million charging points and almost 7,000 H₂ stations
  - Over 200,000 of those must be public chargers with >1 MW
  - Over 250,000 public chargers at truck stops (100 kW)
- Almost $250 billion of cumulative investment needed
  - Half of it for publicly accessible infrastructure
Modeling Framework

**ZET deployment**
- 2040 U.S. ICE phase-out
- 2030-35 in California
- Powertrain split

**ZET activity**
- Energy consumption modeling
- Daily VMT distribution
- Daily energy consumption

**# chargers / H2 stations**
- Is overnight sufficient?
- What fast charging power is needed?
- Utilization rate

**Cost of chargers**
- Hardware & installation
- Learning effects
- Charger lifetime
Powertrain mix of the future fleet

Figure 1. U.S. tractor-trailer sales and stock, assuming a transition to 100% zero-emission vehicle sales by 2040

Fuel-cells are deemed necessary for trucks traveling more than 650 miles a day.

Since both battery and fuel-cell truck technologies continue to evolve, we did a sensitivity analysis on this assumption.
More than 90% of use cases are projected to need publicly accessible infrastructure, based on the energy consumption modeling. Private depot charging is fundamental, but not sufficient.
What infrastructure did we model?

Table 3. Assumptions used in the analysis of the infrastructure requirements for battery electric heavy-duty tractor-trailers.

<table>
<thead>
<tr>
<th>Type of charger</th>
<th>Power (kW)</th>
<th>Charger cost (USD)</th>
<th>Installation costs (USD/kW)</th>
<th>Utilization (vehicles per day)</th>
<th>Charging duration (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overnight</td>
<td>85</td>
<td>100</td>
<td>49,000</td>
<td>27,300</td>
<td>240</td>
</tr>
<tr>
<td>Fast</td>
<td>300</td>
<td>350</td>
<td>134,500</td>
<td>76,300</td>
<td>129</td>
</tr>
<tr>
<td>Megawatt</td>
<td>850</td>
<td>1000</td>
<td>336,000</td>
<td>190,800</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 4. Assumptions used in the analysis of the infrastructure requirements for fuel cell trucks

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of hydrogen refueling station</td>
<td>4,800 kg/day</td>
<td></td>
</tr>
<tr>
<td>Utilization rate, 2021/2050</td>
<td>10%/75% of capacity</td>
<td></td>
</tr>
<tr>
<td>Cost of hydrogen refueling station, 2021</td>
<td>$6,000,000</td>
<td></td>
</tr>
<tr>
<td>Cost of hydrogen refueling station, 2050</td>
<td>$3,300,000</td>
<td></td>
</tr>
</tbody>
</table>
Infrastructure needs until 2050

Figure 2. Number of chargers and hydrogen refueling stations needed to support 100% zero-emission tractor-trailer sales from 2040.
Distribution of needed investment in publicly accessible infrastructure

Ultra fast, 1 megawatt chargers, represent the bulk of the investments.

Between $60 and $80 billion (depending on fuel cell uptake), until 2050

Figure 3. Cumulative investment needed to provide publicly accessible infrastructure to support the U.S. zero-emission tractor-trailer fleet, by infrastructure and expenditure type, from 2020 to 2050
There is low sensitivity to $\text{H}_2$ deployment

- Battery-electric tractor-trailers
- Fuel-cell tractor-trailers
- Ultra-fast chargers
- Hydrogen refueling stations

Cumulative infrastructure investment until 2050 (Billion USD)

- Daily VMT at which fuel cell trucks are assumed to be needed (miles)
- Hydrogen refueling stations needed by 2050
- Ultrafast charging points needed by 2050
Figure 4. Total annual investments in publicly accessible charging and refueling infrastructure for zero-emission tractor-trailers

An average investment of $4 billion per year from 2021 to 2050 will be required on publicly accessible infrastructure.

Most significant investments after 2038, at an average of $7 billion until 2050.
Summary: Fleet of zero-emission trucks

The national fleet of Class 7 and Class 8 tractor-trailers is projected to grow by 3.5% in the next 30 years, totaling around 3 million tractor-trailers in 2050.

Assuming a transition to 100% zero-emission vehicle sales by 2040, by 2050, the 2.4 million zero-emission tractor-trailers operating on U.S. roads will constitute 79% of the entire tractor-trailer fleet.

Table 5. Infrastructure needs of a 100% zero-emission tractor-trailer fleet in the United States

<table>
<thead>
<tr>
<th></th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of zero-emission tractor-trailer fleet</td>
<td>103,000</td>
<td>950,000</td>
<td>2.4 million</td>
</tr>
<tr>
<td>Share of combustion engine tractor-trailers</td>
<td>96.4%</td>
<td>67%</td>
<td>21%</td>
</tr>
<tr>
<td>Share of battery-electric tractor-trailers</td>
<td>3.3%</td>
<td>29%</td>
<td>67%</td>
</tr>
<tr>
<td>Share of fuel-cell tractor-trailers</td>
<td>0.3%</td>
<td>4%</td>
<td>12%</td>
</tr>
</tbody>
</table>
## Summary: Scale of infrastructure rollout

<table>
<thead>
<tr>
<th></th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overnight private chargers (100 kW)</td>
<td>95,000</td>
<td>830,000</td>
<td>2 million</td>
</tr>
<tr>
<td>Overnight public chargers (100 kW)</td>
<td>18,000</td>
<td>125,000</td>
<td>267,000</td>
</tr>
<tr>
<td>Fast chargers (350 kW)</td>
<td>3,200</td>
<td>22,000</td>
<td>43,000</td>
</tr>
<tr>
<td>Ultra-fast chargers (1 MW)</td>
<td>10,500</td>
<td>93,000</td>
<td>220,000</td>
</tr>
<tr>
<td>Hydrogen refueling stations (4,800 kg/day)</td>
<td>220</td>
<td>2,500</td>
<td>6,900</td>
</tr>
</tbody>
</table>

2.5 million charging points and almost 7,000 H₂ stations will be required by 2050. 10% will be publicly accessible fast charging points with more than 350 kW. 11% will be publicly accessible overnight depot charging with more than 100 kW. Overnight depot charging will provide the remaining charging opportunities.
The cumulative investment in publicly accessible infrastructure until 2050 is estimated at $122 billion.

The cumulative private investment in this limited-access depot charging is estimated at $116 billion through 2050.
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Introduction
To decarbonize the U.S. transportation fleet, policymakers cannot ignore heavy-duty tractor-trailers. These combination vehicles, consisting of a trailer pulled primarily by a Class 7 or Class 8 diesel semi-tractor, were approximately 13% of the on-road medium-and heavy-duty fleet in 2020 and generate approximately 60% of its greenhouse gas emissions and fuel consumption. These vehicles are the workhorses of the U.S. transportation fleet, consuming large volumes of diesel fuel while pulling heavy payloads and traveling relatively long distances each year.

THANK YOU

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The Zero Emissions Decarbonization Path

Zero Emission HDV Sales

~100,000 in China (2019)
~28,000 in Europe (2020)
~300 in United States (2020)