Decarbonizing Medium & Heavy-Duty On-Road Vehicles

Catherine Ledna[1], Matteo Muratori[1], Arthur Yip[1], Paige Jadun[1], and Chris Hoehne[1]
[1]National Renewable Energy Laboratory

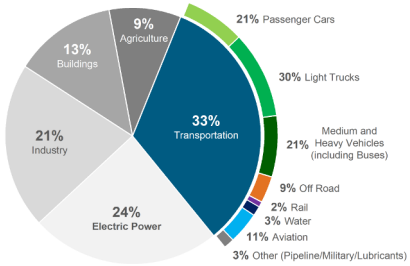
Intro & Motivation

- Medium & heavy-duty vehicles (MHDVs) emit 21% of U.S. transportation GHG emissions
- Decarbonization of MHDVs is necessary to achieve U.S. net zero goals and zero-emission vehicles (ZEV) offer a viable pathway

We explored the following questions:

- When do ZEVs become cost competitive with conventional diesel vehicles?
- What are the vehicle sales, stock, and emissions implications of the transition to ZEVs?

2019 U.S. GHG Emissions



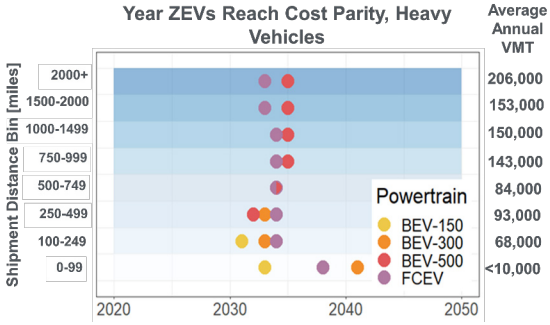
Breakdown of U.S. transportation sector emissions. Figure reproduced from Ledna et al. (2022).

Methods

- The TEMPO model was used to **estimate the total cost of driving for different technologies for all MHDV classes and market segments**.
- **Total cost of driving** includes the following:
  - Upfront capital cost
  - Fuel & maintenance costs
  - Monetized cost of charging time (battery-electric vehicles)
  - Financial horizon
- Vehicle **sales shares** were estimated using a logit formulation
- Vehicle **stock**, **energy** and **emissions** were estimated for each class and market segment

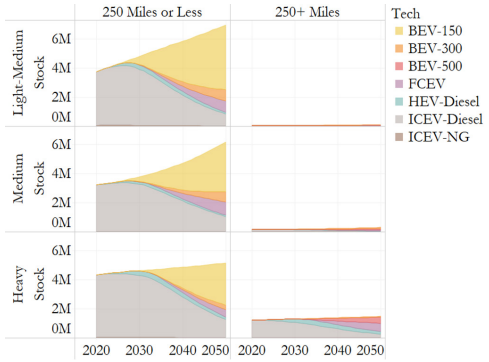
Results

- Under DOE technology & fuels targets largely vetted with industry (central scenario), **ZEVs reach cost parity with conventional technologies in all market segments by 2035**.
- **Short-range BEVs** (150 to 300 miles of range) achieve parity **before 2030 in light-medium & medium vehicle classes.**
- ZEVs achieve parity in heavy market segments **between 2030 and 2035** with **FCEVs more competitive in long-haul applications** due to faster refueling.



Year heavy ZEVs reach cost parity with conventional vehicles by market segment. Figure reproduced from Ledna et al (2022).

MHDV Stock by Class and Shipment Distance



MHDV stock, Central scenario. Stock is divided by vehicle class: light-medium (class 3), medium (class 4-6), and heavy (class 7-8). Figure reproduced from Ledna et al (2022).

Sales, Stock & Emissions

- Under central assumptions ZEV sales reach 42% by 2030 and 100% by 2046
- Slow stock turnover delays impacts; ZEV stock is 7% of the fleet in 2030 and 80% in 2050.
- FCEV sales are concentrated among heavy long-haul vehicles; BEV sales are greatest in short-haul segments
- Emissions reductions are 69% in 2050 relative to 2019 despite assumed VMT growth of 55%.

Key Takeaways & Areas for Future Research

- ZEV offer an affordable pathway to decarbonize MHDVs. Sales could reach 42% of all MD/HD trucks by 2030, reflecting lower combined vehicle purchase and operating costs
- Multiple technologies are viable for different MHDV market segments, including BEVs and FCEVs, suggesting multiple pathways to decarbonization
- Results are highly sensitive to uncertain technology and fuel assumptions; vehicles driving long distances are particularly sensitive to fuel costs
- Future research should include investigation into manufacturing and supply chain constraints, infrastructure and grid requirements, consistent fuel prices, and improved vehicle operation data to refine real-world costs and adoption decisions

This poster is based on work published at: Ledna, C., Muratori, M., Yip, A., Jadun, P., and Hoehne, C. 2022. Decarbonizing Medium & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis. National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy22osti/82081.pdf.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Vehicle Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Fifteenth IAMC Annual Meeting 2022
College Park, MD
29 November – 1 December 2022
NREL/PO-5400-84486