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Activity Patterns of Heavy-Duty Vehicles and Their Implications on Energy Use and Emissions

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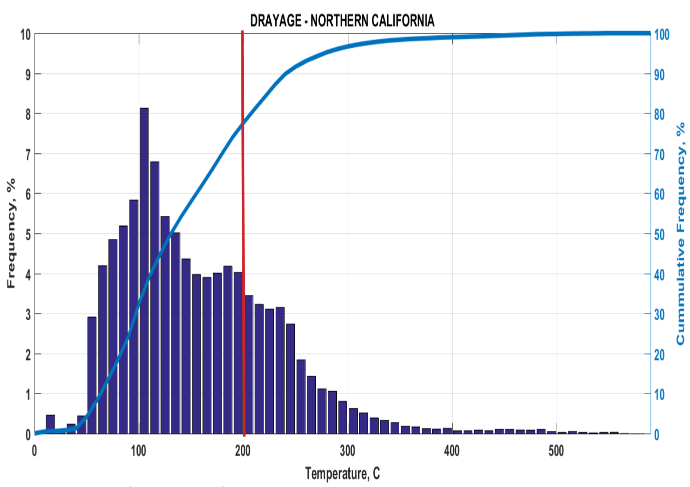
Topic / Issue

Heavy-duty vehicles comprise a variety of vocations whose distinct operational requirements create different activity patterns. Understanding these differences will allow development of appropriate energy and emission reduction strategies.

For instance, many heavy-duty diesel vehicles employ the selective catalytic reduction (SCR) to meet the new 2010 emission standards for nitrogen oxides (NO_x). Typically, SCR needs to be at least 200 ^{O}C before significant NO_x reduction is achieved. Some activity patterns may increase the frequency with which this temperature requirement is not met such as during start-up and idling.

Similarly, the electrification of heavy-duty vehicles is a promising pathway for energy independence and emissions reduction but is complicated by the trade-off between battery size and the driving range necessary for specific operating goals. Detailed knowledge of activity patterns can therefore inform what vocational uses of these vehicles are suitable candidates for electrification.

Research Findings



Drayage trucks in Northern California spend 74% of their operating time with a SCR temperature lower than 200 ^{O}C when NOx reduction technology loses its effectiveness.

The distribution of vehicle miles traveled by speed and by hour of day for drayage trucks in Northern California shows that the trucks operate mostly between 7 a.m. and 4 p.m. It also shows that the trucks generally travel at speeds lower than 35 mph as most of their operation does not require driving on freeways.

In contrast, the same distribution for drayage trucks in Southern California shows that they operate during both daytime and nighttime, likely because of the "OffPeak" pricing program that encourages nighttime operation to alleviate the congestion at the ports and nearby roadways. The data also show that most of their miles occur at highway speeds between 40-55 mph as a significant portion of their operation involves locations far away from the ports, which require driving on freeways.

KEY TAKEAWAYS

- A rich set of vehicle and engine activity data has been collected from a variety of heavy-duty vehicle vocations and analyzed to reveal their real-world operation patterns.
- The data show that activity patterns of heavy-duty vehicles vary greatly by vocation, and in some cases, also by geographic area.
- A notable portion of real-world operation of heavy-duty diesel vehicles may be under situations that would result in higher NOx emissions than the limits in the current standards.

"Due to the great variety of their operation, there is no one-size-fits-all alternative fuel/vehicle technology for heavy-duty vehicles."

Findings (continued)

The frequency distributions of SCR temperature for both out-of-state and in-state line haul trucks have two peaks. One of the peaks is around 260-280 ^{O}C, which is probably when driving on highways. The other one is around 100 ^{O}C, which is probably when idling.

In contrast, the drayage truck in Northern California comes from the same fleet as the out-of-state line-haul trucks, but has a significantly different frequency distribution of SCR temperature where the distribution has a single peak at around 100-110 ^{O}C. This is a strong evidence of how the differences in vehicle activity patterns affect the SCR temperatures of the vehicles, and likely their real-world NO_x emissions.

Overall, the vehicles in this study operate with SCR temperature lower than 200 ^{O}C for 11-87% of the time, depending on their vocation type.

Approach

Vehicle and engine activity data were collected from 90 heavy-duty vehicles that make up 19 different groups defined by a combination of vocational use, weight class, and geographic region. These include in-state line haul, out-of-state line haul, drayage in Northern California, drayage in Southern California, construction, food distribution, beverage distribution, refuse, and utility repair, among others. Almost all of the vehicles are of model year 2010 or newer and are equipped with the SCR technology. The data were collected using advanced data loggers that recorded data about vehicle speed, position, and more than 170 engine parameters at the frequency of one Hz. These data went through several steps of data processing and quality assurance to identify road type, filter and correct erroneous data, and protect fleet confidentiality. The processed data were then used to analyze a number of statistics related to engine start, engine soak, idle activity, SCR temperature, and other factors.

Conclusion / Recommendations

- This research has shown that activity patterns of heavy-duty vehicles differ greatly by vocation, and in some cases, also by geographic area. More data may be collected from additional vehicles to further characterize the variability in activity patterns for each vehicle group.
- Because of the great variety of operations performed by heavy-duty vehicles, there is likely to be no one-size-fits-all alternative fuel/vehicle technology for heavy-duty vehicle fleets. Therefore, it would be prudent to promote a diverse mix of alternative fuel/vehicle technologies, and then provide assistance to fleets in selecting the technology(ies) that meets the needs of their operation the most.
- The analysis results of SCR temperature imply that a notable portion of real-world operation of heavy-duty diesel vehicles may be under situations that would result in higher NO_x emissions than the limits in the current 2010 standards. A new approach to limiting NO_x emissions from heavy-duty diesel vehicles that replaces or supplements engine certification with real-world monitoring may be worth exploring.

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