Quantifying CO_2 Emissions Benefits of Hybrid Electric Municipal Trucks Using In-Use Data and Vehicle Simulation

Background

The performance of hybrid and conventional vehicles has been extensively compared for passenger cars, but has not been quantified for all vehicle types and driving cycles. For example, common knowledge says that hybrid vehicles get better fuel mileage in cities where frequent stops allow the battery to recharge more often through regenerative braking, improving miles per gallon by up to 20-50% [1]. However, changes in fuel economy specific to a driver's route; i.e. the exact mix of highway, arterial, and city driving, is less known. This idea is especially relevant to vehicles purchased to perform unique duties, like for municipal fleets in cities and counties where the driving cycles are distinct from routes driven by the average passenger car driver.

Most municipalities including state departments of transportation, counties, and cities frequently invest in large vehicle fleets for performing a large array of tasks from road maintenance to highway enforcement. Fleet managers currently collect vehicle data to improve their operations; however, a large amount of collected data is not utilized. Such data includes information on fuel consumption, engine speed, and GPS location. As counties look more into hybrid vehicles to meet goals for improving fuel economy, this underutilized data could be important to compare conventional and hybrid vehicle performance. Fuel consumption offers direct quantitative data on a vehicle's environmental impact because it is proportional to CO_2 emissions as every carbon molecule in the burned fuel is turned into CO_2.

Hybrid electric vehicles have been marketed to municipal fleets as a way to lower fuel economy and CO_2 emissions. However, it is unclear whether the additional cost associated with hybrids is comparable to fuel savings, especially for the specialized driving cycles performed by these vehicles. This project's goal is to use data collected from in-use vehicles in a Minnesota county fleet and computer simulation to investigate the CO_2 emissions benefits of hybridization.

Question

How does route choice impact CO_2 emissions benefits of a mild hybrid electric pickup truck compared to a conventional pickup truck?

Hypothesis

CO_2 emission reductions from a mild hybrid electric pickup truck are highest for mixed urban routes with significant starting and stopping combined with some high speed driving.

Methods

Dakota County, MN has recently purchased two mild hybrid vans from XL Hybrids, a vehicle conversion company. Data from this vehicle will be used to build and validate a vehicle simulation to achieve the stated project goal. Computer simulation is a powerful tool for determining powertrain performance because it allows testing various duty cycles without physical measurement. For this experiment, data collected on the XL hybrid truck with be inputted into AVL cruise software to create a digital vehicle model. AVL cruise is a powerful, robust and adaptable simulation tool for vehicle driveline system analysis [2].

The first step of this experiment will be to collect information including vehicle properties such as engine size, tire weight, etc. on the XL mild hybrid pickup truck in order to build the AVL cruise model which will take approximately three weeks. Two weeks will be allotted to running the model through several routes and settings, modeled after average routes of in-use municipal vehicles to calculate the routes resulting in the highest and lowest fuel consumption. Output from simulations will include fuel efficiency, driving emissions and performance analyses. To confirm the accuracy of the AVL cruise model, two weeks will be allotted to the collection of data on in-use vehicles using a UMN-developed Raspberry Pi microprocessor-based controller as a vehicle logger.

An analysis of all data collected for several routes will be used to predict future fuel consumption and CO_2 emissions for the mild hybrid truck. Results will be compared to the same predictions previously made from a conventional truck model to determine when use of the hybrid truck is most optimal. Comparison will determine route-dependent cost effectiveness and environmental advantages between the different vehicles. Three weeks will be alloted to the analysis and comparison of results. Finally, two weeks will be alloted to preparing a poster presentation of the results of the experiment.

Significance

The aim of this experiment is to supplement current research headed by Prof. Northrop, with a goal of reducing expenses for fleet-owning municipalities while simultaneously reducing environmental impact of their vehicles. A greater understanding of powertrain performance of hybrids for different routes will help counties make informed decisions on the types of vehicles to employ for specific purposes. Dakota County has 249 vehicles in their fleet. Therefore, more environmentally conscious decision making in the purchase could have significantly positive environmental impacts. As vehicle fleets are costly for counties -- $541,673/yr for Dakota county -- the optimization of hybrid vehicle use will also reduce fuel costs and therefore benefit taxpayers.

References

1. Ahn, J.K., Jung, K.H., Kim, D.H. et al. Int.J Automot. Technol. (2009) 10: 229. https://doi.org/10.1007/s12239-009-0027-z (last accessed 2/15/18).

2. https://www.avl.com/cruise (last accessed 2/15/18).