Real-World Emissions from Hydrogen Substitution with a Heavy-Duty Diesel Truck

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About the projects

Hydrogen can substitute up to 40% of diesel energy in co-combustion fuel systems to lower CO2 emissions from heavy-duty trucking. However, the impact of hydrogen substitution on particulate matter (PM) and NOx emissions has not been studied in real-world travel conditions, only under laboratory conditions. A portable emissions measurement system (PEMS) was developed at to UBC measure the CO2, NOx and PM emissions from a heavy-duty truck capable of hydrogen/diesel co-combustion during 2,500 km of routine travel. The PEMS showed that hydrogen supplied 24% of the energy from co-combustion during travel, leading to 25% fewer CO2 emissions, similar PM emissions, and 10% higher NOx emissions compared to sole diesel combustion.

Project Highlight:

Diesel engines have found widespread use in heavy-duty transportation because of their durability and fuel efficiency but are also a source of considerable CO2 emissions. To maintain the well-established diesel infrastructure while lowering its environmental impact, hydrogen can be used to displace petroleum-based diesel in existing engines with minimal modifications. Hydrogen is typically produced from natural gas reforming, a non-renewable feedstock, but hydrogen with a lower CO2 footprint can be sourced from electrolysis using renewable electricity or recovered as a waste from chemical processes. The primary byproduct of pure hydrogen combustion is water, and thus avoids CO2, SOx, unburned hydrocarbon, and particulate matter (PM) emissions that are pervasive in diesel engines. Hydra Energy is a company based in Delta, BC that sources hydrogen from industrial waste and retrofits semi-trucks with the capacity to co-combust with diesel. Trucks modified with the dual fuel system can displace up to 40% of the diesel energy content with hydrogen. The retrofit is reversible and done at no cost, while hydrogen is supplied at a 5% discount from diesel. Moreover, the displaced diesel qualifies for low carbon fuel standard credits from the government. Thus, the implementation of a dual-fuel co-combustion system has financial and environmental incentives.

For more details of this project, visit:

- Hydra Energy (*link*)
- Profile of Dr. Patrick Kirchen (*link*)
- Profile of Dr. Steven Rogak (*link*)
- The effect of hydrogen substitution on the real-world CO_2, NOx, and PM emissions of a heavy-duty diesel truck (*link*)

Hydra Energy partnered with UBC to assess the real-world impact of the dual-fuel co-combustion system by commissioning a portable emissions measurement system (PEMS) to measure the exhaust composition of CO2, NOx, and PM during on-road operation of a semi-truck. NOx can increase with more substitution of diesel with hydrogen because the high adiabatic flame temperature of hydrogen can create warmer cylinder temperatures that are more favourable towards thermal NOx formation. Conversely, NOx can decrease with hydrogen substitution as some air is displaced, resulting in less O2 availability in the cylinder, while the high heat capacity of water from hydrogen combustion can dampen the increase in cylinder temperature. PM formation also has competing mechanisms that can affect the overall emissions. PM can decrease with hydrogen displacement because less carbon is available to form soot. However, higher displacement of diesel with hydrogen also displaces air, which creates richer conditions in the cylinder that are favourable to PM formation. Although standardized test cycles are used to assess vehicle emissions, these do not model real-world driving conditions. The PEMS allowed for one of the first instances that measured the on-road emissions from a hydrogen/diesel heavy-duty truck. The PEMS recorded the position, driveshaft torque, as well as the pre-aftertreatment exhaust concentrations of CO2, NOx, and PM at a frequency of 10 Hz as the truck travelled more than 2,500 km across BC with either diesel or diesel/hydrogen co-combustion. This study mapped out the hydrogen displacement, as well as CO2, NOx, and PM emissions at different engine loads and speeds. Overall, hydrogen displaced 24% of the total energy that would otherwise have been supplied by diesel, resulting in 25% fewer CO2 emissions, similar PM emissions, and 10% higher NOx emissions compared to operation with only diesel.