HDV Optimal Deployment of Clean Vehicles and Fuels

Executive Summary

Background

The state of California has ambitious environmental goals, including but not limited to a 40% reduction in GHG emissions compared to 1990 levels by 2030, an 80% reduction by 2050, and economy-wide carbon neutrality by 2045. Transportation-specific carbon goals include a reduction in carbon in transportation fuel by 20% in 2030. Criteria pollutants, predominantly related to heavy duty vehicle (HDV) activity, are also of critical importance due to their negative impacts on human health. Transitioning to biofuels can result in reduced GHG emissions but does not necessarily reduce criteria pollutant emissions as much as a fully ZEV fleet with electricity and electrolytic hydrogen fuel. Given these constraints, a holistic approach is needed to assess which alternative fuel and energy sources can be generated in the future. A more accurate assessment of the best uses of California's feedstocks for the support of HDV emissions goals will help inform optimal HDV fleet choices in the long-term.

Objectives and Methods

The goals of this study are to determine optimal fuel pathways for the heavy duty sector in California and provide guidance on policy and economic mechanisms that should be implemented to help overcome barriers to zero and near-zero emission heavy duty vehicle adoption from both a technical and a fleet perspective. For this study, on-road vehicles between class 2B and 8 are considered. These goals are met by (1) determining the best use of renewable feedstocks in California, (2) quantifying the potential reductions in the emission of GHGs and criteria pollutants through the use of a broad range of connected and automated vehicle (CAV) technologies and efficiency upgrades in the heavy duty sector, (3) creating multiple long-term heavy duty fleet mix scenarios, (4) developing a guidance document for fleets transitioning to alternative fuels, and (5) providing guidance on overcoming barriers to implementing zero and near-zero emission heavy duty pathways.

Investigating optimal use of renewable feedstocks in California was accomplished through a techno-economic analysis to determine resource potential, costs, conversion yields, and viable pathways for biofuels, electricity, and electrolytic power-to-gas technologies for the production of renewable natural gas (RNG) and hydrogen. These data are compiled through a literature review in order to establish existing and near-term fuel pathways for the heavy duty sector, and Wright's Law was used to project fuel production costs into the future. The impact of electricity use and electrolytic hydrogen production for HDVs on the electric grid was modeled using the Holistic Grid Resource Integration and Deployment tool to determine probable impacts on renewable utilization, transportation and grid emissions, and levelized cost of energy. A heavy duty vehicle charging model was developed for this study based on California HDV travel patterns to examine a range of vehicle-grid integration scenarios including vehicle-to-grid.

For this study, an extensive literature review was also conducted to determine the impact of CAV and efficiency upgrades on the heavy duty sector. Potential costs, barriers to use, GHG and criteria pollutant reductions, and impacts on disadvantaged communities from CAV adoption were compiled. Disadvantaged communities (DACs) were identified with the use of CalEnvironScreen 3.0. Fuel savings at the state level were calculated out to the year 2050 for different scenarios spanning the range of fuel changes reported in literature and examining different adoption timeframes. The baseline fuel consumption, vehicle miles traveled, and vehicle turnover come from CARB's Vision model.

The fuel pathways and associated costs, vehicle miles traveled data from EMFAC, and future vehicle characteristics including fuel efficiency, range, and powertrain costs were then incorporated to develop multiple heavy duty fleet mix scenarios that will allow California to meet its long-term climate and air quality goals. The model projections consider improvements in vehicle efficiency and the impacts of the availability and costs of fuel and infrastructure.

The guidance document developed for this project is based on the feedback gathered from fleet managers, and researchers, as well as a review of other published reports and peer-reviewed literature. Questions directed to fleet managers and other relevant experts were focused on identifying challenges, costs, barriers, and tradeoffs, and potential solutions to overcome barriers, associated with investing in low carbon fuels and advanced technology. This included timeframes for technology diffusion within fleets, and discounting decisions applied to fuel costs versus capital costs. The results of the literature review and interviews were distilled with the intent to provide easy guidance for fleets that are considering transitioning to alternative vehicles and/or fuels, or that have already begun that transition.

Complementary to the fleet guidance document is a review of current policies, focusing on federal and state incentive programs, in order to provide guidance on implementing effective future policies and programs that support zero and near-zero emission heavy duty pathways.

Results

The cost of electricity as an HDV fuel is greatly affected by infrastructure cost, which in turn is greatly affected by the assumed charging power, i.e., Level 1, Level 2, or Level 3. In addition, the use of intelligent charging strategies (e.g. smart charging and vehicle-to-grid) can allow vehicle operators to schedule charging to correspond with lower electricity cost periods. This is limited by access to infrastructure, such as availability along routes or at home base locations. The infrastructure then directly impacts the feasibility of heavy-duty BEVs. Generally, hydrogen costs are slightly above level 3-dispensed electricity. Electrolysis is a relatively efficient production method but requires cost reductions and a low carbon electric grid to facilitate deep GHG reductions. Conversely, the gasification of biomass allows for the use of very low or negative carbon intensity (CI) biomass which can be a cost-effective method of producing renewable hydrogen in the near- to mid-term. RNG is most efficiently and cost-effectively produced by gasification of biomass feedstock unless a cheap source of carbon can be obtained for use in methanators to facilitate electrolytic pathways. Renewable diesel has a moderate cost compared to other renewable HDV fuels. Because it is a drop-in fuel for current infrastructure and vehicles, using renewable diesel can be a cost-effective method of meeting GHG goals if negative CI biomass such as manure and food waste are used. Additional revenue streams can provide important cost reductions for certain fuels but not others, e.g., the Low Carbon Fuel Standard (LCFS) and Renewable Fuel Standard (RFS) can offer significant cost reductions to renewable diesel and electricity, both of which see reductions of approximately 30-60% depending on pathway. The cost of hydrogen and RNG fuel is not as impacted, though reductions of up to 15% are realized for hydrogen and 19% for anaerobic digestion.

Demonstrations of CAV technologies in the HDV sector have shown significant fuel savings associated with eco-driving and platooning strategies. However, there is limited literature on CAV impacts on DACs and the state as a whole. When constrained by existing GHG and criteria pollutant emissions legislation and goals, renewable diesel and hydrogen, produced from electricity and various biomass sources, along with electricity are the primary fuels projected to be used. Heavy use of negative CI biomass is needed to meet GHG constraints. When constrained by increasingly strict ZEV mandates, electricity and hydrogen are the only renewable fuels considered in the long-term, although RNG is used in the short- and medium-term as a transitory fuel. It is important to note that the overall cost is only slightly higher for the high ZEV assumption and that scenario attains other benefits including lower pollutant emissions and lower annual costs until 2040. Fossil diesel is projected to be used in decreasing amounts in the near-future, and fossil natural gas is used in the mid-future. A ZEV scenario uses electricity as a primary fuel and fuel feedstock, while waste, agriculture, and forestry biomass are used in gasifiers to produce hydrogen. While this scenario does not meet 2030 GHG goals, the resulting 2050 GHG emissions are significantly lower than an 80% reduction. Policies (e.g., incentives and pricing) can support the use of zero and near-zero emission, heavy duty vehicles, infrastructure and fuels, as well as promote the responsible use of CAV technologies, to achieve the State's long-term climate and air quality goals.

Conclusions

Renewable HDV fuel availability is limited by biomass availability but far less limited by electricity availability. An enhanced understanding of biomass allocation is needed to determine the actual availability of HDV fuel production relative to other sectors including aviation, marine, off-road, etc. Given the limited quantities of biogas and biomass feedstocks, as well as potential demands from competing sectors, electrolytic fuels will very likely be required in large scale transitions to hydrogen or RNG in the HDV sector. Support for electrolytic fuels will likely be required across the full fuel pathway (production, distribution, and dispensing) including novel mechanisms for the provision of cost-effective electricity (e.g., developing electric rate structures specific to transmission-connected renewable fuels facilities).

Planning for the allocation of California's biomass resources should be a high priority as biomass availability for HDV renewable fuel production affects resulting fuel pathway and vehicle powertrain projections. Heavy use of net negative or very low CI biomass to meet GHG goals reduces the near- to mid-term ZEV adoption rate which could result in higher GHG emissions long-term compared to a scenario characterized by aggressive adoption of ZEV despite similar total costs. Also, altering the negative CI value of biomass to reflect a change in standard practices (e.g. SB 1383) can yield challenges in meeting long term goals. More clarity on how California's GHG laws and goals will be implemented on a sector-by-sector basis is needed to determine what emissions reductions should be targeted by each sector. The fleet guidance document developed for this project can provide step-by-step guidance for fleets transitioning to alternative fuels. Additionally, simplifying and consolidating incentive programs to create a "one-stop shop" where fleets can acquire both vehicles and supporting infrastructure can accelerate zero and near-zero emission vehicle adoption.