STRATEGIES FOR TRANSITIONING TO LOW-CARBON EMISSION TRUCKS IN THE UNITED STATES

DRAFT Executive Summary for STEPS Review, May 2015

A White Paper from the Sustainable Transportation Energy Pathways Program at UC Davis and the National Center for Sustainable Transportation

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STEPS White Paper Process

The Sustainable Transportation Energy Pathways (STEPS) Program prepares white papers that synthesize research insights from various projects, to help address complex sustainable transportation transition issues and inform the discussion for decision makers in industry, government, and civil society. This white paper has already undergone significant rounds of peer review by the entities listed in the Acknowledgements section below. The research team is now providing all STEPS consortium members, including sponsors and outside experts, an opportunity to review and provide comments. We look forward to reviewing and incorporating thoughts into the next version of this white paper, which is slated to be released publically on April 30, 2015. Following a public release, the research team seeks to publish this paper in a peer-reviewed journal.

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Acknowledgments

This study was made possible with funding from the Institute of Transportation Studies' STEPS Program at UC Davis and from the National Center for Sustainable Transportation (NCST). The NCST is supported by the U.S. Department of Transportation. Funding from STEPS sponsors and the California Energy Commission contributed to the research that is presented in this paper.

The authors would like to thank Ben Sharpe for developing the TOP-HDV model as part of his dissertation research and for providing assistance in augmenting certain aspects of the model for this project. They would also like to thank reviewers at the California Air Resources Board, California Department of Transportation, California Energy Commission, California Trucking Association, Cummins Inc., Georgia Institute of Technology, New York State Department of Transportation, New York State Energy and Research Development Authority, Port of Los Angeles, Rochester Institute of Technology, South Coast Air Quality Management District, U.S. Energy Information Administration, University of California Davis, and University of California Riverside for providing excellent review comments on preliminary versions of this white paper.

Strategies for Transitioning to Low-carbon Emission Trucks in the United States

EXECUTIVE SUMMARY

The United States and California have both made commitments to an 80% reduction in energy-related greenhouse gases (GHGs) from 1990 levels by 2050 in order to help stabilize atmospheric concentrations of greenhouse gases, though not at the specific level of transportation or an individual transport mode.

This White Paper reviews previous studies and provides a new investigation into the feasibility of achieving an 80% reduction in CO_2 emissions ("80-in-50") in the U.S. and California from trucks in the 2050 time frame. We assess the technological and economic potential of achieving deep market penetrations of low carbon vehicles and fuels, including vehicles operating on electricity, hydrogen, and biofuels.

This paper provides a side-by-side comparison of potential truck technologies and fuels, and analyzes the technical, economic, and other challenges associated with the various options. Finally, it presents several scenarios for achieving an 80-in-50 target for trucks.

Overall, we find achieving such a target for trucks will be very challenging and, if focused on hydrogen and electric zero emission vehicle (ZEV) technologies, would require strong sales growth beginning no later than 2025 and nearly a complete transition to sales of these vehicles by 2040 to achieve needed stock shares by 2050. We find that introducing sizable quantities of low-GHG biofuels compatible with today's diesel engines can ease the transition time to ZEVs or even cut needed ZEV shares significantly, but this involves other very challenging aspects. This paper does not consider local pollutant emissions such as NOx, which in some places (notably California) could require an even faster transition to ZEVs

Key Findings

This paper reviews estimates of truck CO_2 reduction potentials and costs and develops new scenarios to 2050 focused on an "80-in-50" target. These scenarios indicate that a combination of strong uptake of zero-emission trucks and advanced biofuels will likely be needed to hit such a target, but even with this combination it is a very challenging target.

The costs of deploying ZEVs and advanced biofuels to reduce truck GHG emissions may be substantial in the near term but should decline over time, relative to a baseline scenario.

The number of ZEV trucks (and the sales trajectory) that could be needed by 2030 suggests that policies targeting the sales of ZEVs may be needed as a complement to fuel economy standards. Similarly, policies may be needed to ensure that sustainable, low-carbon hydrogen and diesel-replacement biofuels become available in large volumes in the coming decades.

than called for by climate-related goals. We do not attempt to determine which strategy (ZEVs or biofuels) is superior and conclude that a combination is the most likely way to achieve large reductions in GHG emissions going forward. The tradeoffs involved – notably the ease of biofuels' fleet penetration versus the reduction of criteria pollutants offered by ZEVs – may ultimately determine which path is chosen in different markets.

Presently trucks dominate goods movement in the U.S., carrying 72% of the tonnage, 42% of ton-miles, and 70% of the goods value. The truck scenarios developed for this paper include eight different truck types, with a high share of truck miles and fuel use accounted for by long haul Class 8 trucks, although short haul heavy duty trucks and commercial pick-up trucks are also important.

In reviewing three prominent studies of low-carbon truck futures, we note the lack of a clear consensus of an optimal pathway or even the feasibility of achieving 80-in-50. Two studies focused primarily on the potential for significant utilization of biofuels for heavy-duty vehicles, with both studies projecting emissions reductions far short of an 80% reduction target. A broader third study in 2012, by the California Air Resources Board (ARB), achieved an 80-in-50 target with massive uptake of ZEV trucks, but even this approach did not meet ARB's 2032 NOx targets. These three studies, along with the new scenarios presented in this paper, suggest that without strong adoption of very low carbon biofuels, it will take a very rapid ramp-up of ZEV trucks (i.e. fuel cell and/or electric trucks) beginning shortly after 2020, with a full penetration of these vehicles by 2040, to have a chance for an 80% reduction in CO_2 emissions by 2050. The urgency of this transition to ZEV trucks could be eased considerably by concurrently introducing large quantities of low-carbon biofuels.

The new truck technologies and propulsion systems discussed here include diesel hybrids, liquefied natural gas (LNG) vehicles, biofuels, fuel cells, plug-in hybrid, and battery electric vehicles (with only fuel cells and pure battery electric vehicles considered as ZEVs). Given what is known today, the cost of owning and operating these alternative technologies and fuels would exceed that of diesel trucks, at least in the near term. In the case of biofuels, the vehicle capital cost is the same, but near term fuel costs are significantly higher. If costs of technologies like hydrogen fuel cells and batteries, and the cost of biofuels, decline as we assume in our 2030 cost projections, the costs of a very low carbon scenario over the next 2-3 decades appear moderate in the context of overall trucking costs. In the case of our projections for heavy-duty long haul trucks, the costs between 2030 and 2050 actually are well below those in the base case due to rising fuel savings. But transition costs over the next 1-2 decades may be high.

As with light-duty vehicles, the challenges for large ZEV trucks include deploying a refueling infrastructure that supports widespread adoption of vehicles, and reducing cost barriers through scale and learning. Strong policies are likely to be needed to overcome these challenges, and set ZEV truck sales on a rapid growth trajectory. Ongoing research, development and demonstration (RD&D) programs coupled with fiscal incentives for low carbon fuel adoption by trucks appear critical; a ZEV requirement in the truck sector, like the California requirement for light-duty vehicles, may also be useful but could be more difficult to manage than for cars given the wide range of truck types and purposes. Fiscal incentives for ZEVs may be an alternative or complementary policy to consider.

Scenario results

In the scenarios created for this paper (described and documented in the report and Annex), separate estimates of vehicle market shares and fuel requirements in 80-in-50 scenarios were made for California and the U.S. The underlying growth in truck vehicle miles traveled (VMT) is projected somewhat differently by ARB and the U.S. Energy Information Administration (EIA). ARB projects about a 50% increase in California truck miles between 2010 and 2050, and EIA projects an 80% increase nationally. Given either of these projections, this substantial VMT growth increases the challenge of achieving 80-in-50. However, the scenarios here include enough efficiency improvement in diesel trucks to completely offset VMT growth in CA and mostly offset growth nationwide. Additional efficiency improvement comes from shifts to battery electric and fuel cell trucks, further lowering demand for those fuels in 2050 (though still requiring orders of magnitude increases compared to today). The final contributions to GHG reductions come from deeply decarbonized fuel.

The tradeoff between ZEV sales and the use of biofuels is depicted in Figure ES-1, where a "high ZEV" scenario focused mainly on ZEVs along with very low GHG hydrogen or electricity, is compared with a "Mixed" scenario of 60% blends of very low carbon GHG biodiesel blended into fossil diesel fuel by 2050. The difference is striking, particularly in the 2030-2040 timeframe, when in the ZEV scenario very high sales shares of ZEVs must be achieved to be on a path to 80% GHG reduction, whereas these sales shares can be much lower in the high biofuels scenario. In a ZEV dominated scenario, with a flat rise in ZEV market share over time, ZEVs must account for close to 40% of new truck sales by 2030 and account for nearly all new trucks by 2040 in order to hit an 80-in-50 target. If ZEVs are not close to achieving this type of market share growth by 2030, it probably means they will not be able to achieve an 80-in-50 goal without the help of very large volumes of biofuels.

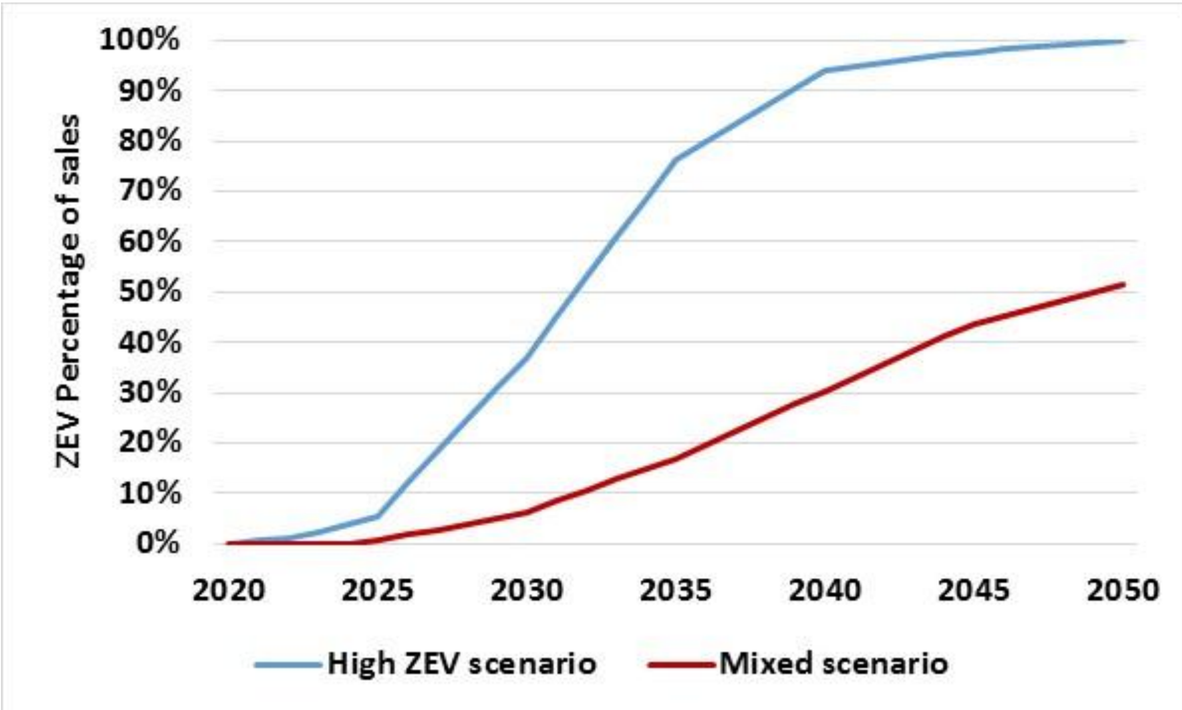

Figure ES-1. Required ZEV sales share to hit 80-in-50 target with no biofuels v. scenario with 60% biofuels blends by2050

The resulting fuel use by fuel type in these scenarios is shown in Figure ES-2, both for a ZEV-dominated scenario and a mixed scenario. Either way, total truck fuel use in 2050 is well below baseline fuel use in 2010, although the use of hydrogen, electricity and (especially in the mixed scenario), biofuels use is far higher than in 2010, when it is quite low for trucks. Further, these fuels are assumed to be deeply decarbonized by 2050: biofuels have an average 80% lower carbon intensity (CI) than diesel, and hydrogen has an 80% lower CI in California and 85% lower in the U.S. context in order to reach the overall 80% reduction in GHG emissions. This reduction in CI is dramatic, so these scenarios also involve moving to new generations of feedstocks and fuel pathways, such as cellulosic drop-in biofuels and hydrogen from renewable sources. Producing this much volume of low-carbon fuels will be very challenging, particularly considering that such fuels will also be demanded for use in other modes.

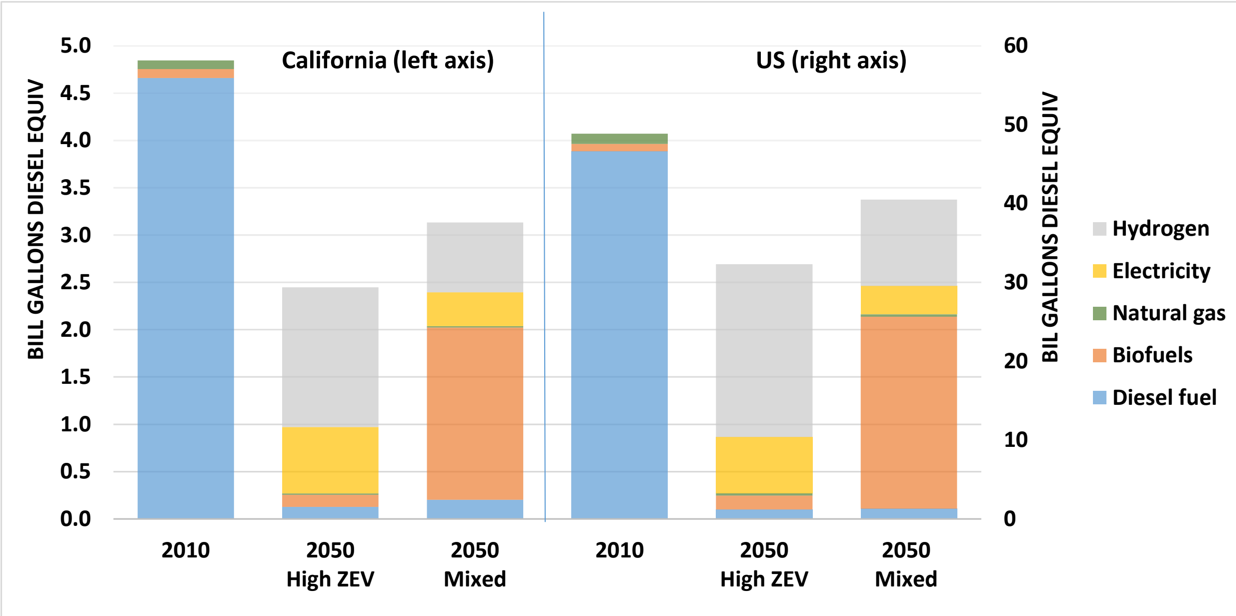

Figure ES-2. Energy use by fuel type, year and scenario, CA and US results

Conclusions

This White Paper finds that achieving an 80-in-50 target for trucks will be very challenging, and it will likely take a combination of strong efficiency improvements and rapid uptake of new vehicle types and fuel types to achieve, with hydrogen fuel cells and biofuels possibly both playing very important roles and electricity playing a smaller role. But since the ultimate role of each energy pathway is unclear, it seems wise to pursue all these technologies and fuels in combination, possibly for another 15 years or more, at least until a dominant pathway emerges. An equilibrium combination may also emerge, which may vary by truck type and use. Even with a combined strategy, the targets for each fuel and vehicle type will be challenging, but likely less so than for a single-pathway approach.

Regardless of the specific scenario or strategy adopted, strong policies would be needed in order to achieve a low carbon truck future. This White Paper has reviewed a range of existing and potential policies. We find that the main policy in place at this time is the national fuel economy standard for trucks. This policy, assuming considerable tightening over time, will likely play a critical role in cutting fuel use and CO_2 emissions, but to reach very low CO_2 levels it may also be necessary to encourage (or require) trucking firms to adopt new types of vehicles and fuels; for this change to happen, other policies will likely be needed, such as new alternative fuel-related incentive programs or truck ZEV requirements. Regarding the large volumes of advanced, low-GHG biofuels in these scenarios, new policies that complement or go beyond the Renewable Fuel Standard and California's Low-carbon Fuel Standard may be needed to encourage a rapid migration to and ramp-up of such biofuels, which are typically derived from waste materials and cellulosic feedstocks, and to "drop-in" biofuels such as "renewable diesel" fuel that can be used in any proportion in diesel engine trucks. Policies would also need to address and help overcome sustainability-related obstacles such as indirect land-use change.

Additional research is needed in a number of areas, including a more detailed analysis of the driving cycles of different types of trucks, how suitable electricity and/or hydrogen is for these various truck types, and how refueling infrastructure transitions can be optimized. An assessment of the maximum realistic rates of market uptake of ZEVs is also needed. Better understanding of some fuel pathways is also needed, such as renewable natural gas (RNG), which could provide a clear pathway starting with natural gas trucks leading to RNG that can achieve a low carbon future. The potential availability and cost of RNG are critical uncertainties at this time. Technologies that would extend the driving range of long haul ZEV trucks (e.g. catenary and dynamic wireless charging systems) also deserve research attention.

In addition, a better understanding is needed of how trucking companies make purchase decisions would be valuable, including the effect of expected truck holding times and turnover rates, the importance of truck resale value and demand for (or aversion to) new technologies in secondary markets, and how purchase decisions vary by company size and type and by truck type.

Finally, this paper has not looked at the potential to cut fuel use and GHG emissions via changes in freight movement. The baseline truck VMT projections are unchanged in our low-GHG scenarios. A broad understanding of the potential to cut truck VMT and energy use via urban logistics, dispatching, information/communication technologies, automation, modal shift to rail, and truck in-use fuel-economy improvements (e.g. from ecodriving), among other things, is needed.