Launch of new STEPS Energy Futures Report:

Technology and Fuel Transition Scenarios to Very Low Greenhouse Gas Futures for Cars and Trucks in California

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ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

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California is committed to a very low carbon future

- California has at least three targets relevant to this study:
  - A 40% reduction in GHGs by 2030, relevant to 1990
  - An 80% reduction in GHGs by 2050, relevant to 1990
  - Full carbon neutrality across the economy by 2045
- In none of these cases is the role of, or targets for, the transportation sector specifically identified
  - It is not clear exactly what role the sector will need to play but clearly it will need to get to very low GHG emissions by 2050 to avoid other sectors having to go well below zero.
- We decided to focus on an 80% reduction strategy for both LDVs and trucks/buses, separately and together, to better understand what hitting this target will involve, and what it may cost.

Boundaries and Ground rules (1/2)

- The study is focused on vehicles and fuels – no changes in LDV and truck travel relative to baseline trends are included in other scenarios

- The study is focused on GHG (CO2e); we do not attempt to track pollutant emissions or understand how hitting *e.g.* NOx targets might change an optimized future pathway.

- The study employs some cost minimization work, and vehicle choice analysis, but ultimately is a backcast showing two possible ways to reach an 80% GHG reduction target.

Boundaries and Ground rules (2/2)

- The study considers transitions to ZEV vehicles (battery electric and fuel cells) and to very low carbon pathways to produce the relevant energy carriers (electricity and hydrogen).

- It also considers transitions to advanced, very low carbon, probably mostly cellulosic derived biofuels.

- Finally, we estimate the cumulative costs of these scenarios, from 2015-2050, including vehicle purchase and fuel purchase costs, that reflect changes in technologies and systems built into the scenarios.

We have created three vehicle/fuel scenarios

- Business as usual (BAU) Scenario
  - Continuation of past trends, no new policies after 2017 reflected
  - LDV ZEV target to 2025 reached, Truck ZEV rule not reflected

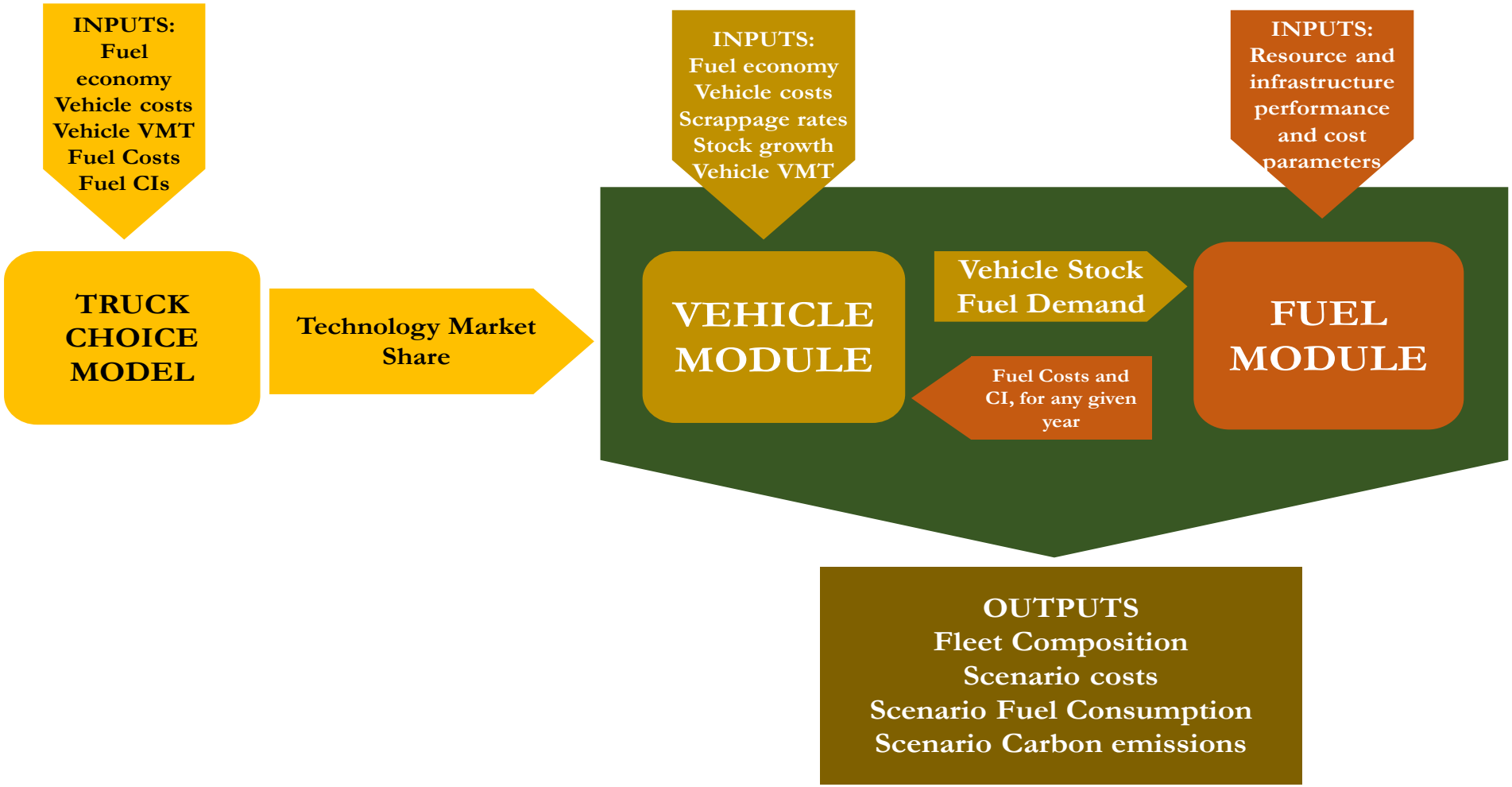
- ZEV Scenario
  - High ZEV market penetration (up to 100% sales shares in 2050). 80% GHG reduction in 2050 from 1990.

- ZEV + Biofuels (ZEV+B) Scenario
  - Lower ZEV market penetration. Advanced biofuels (cellulosic ethanol and renewable diesel, RNG), are grown to help it reach the 80% GHG reduction target

We have used 2 models to help us in the analysis

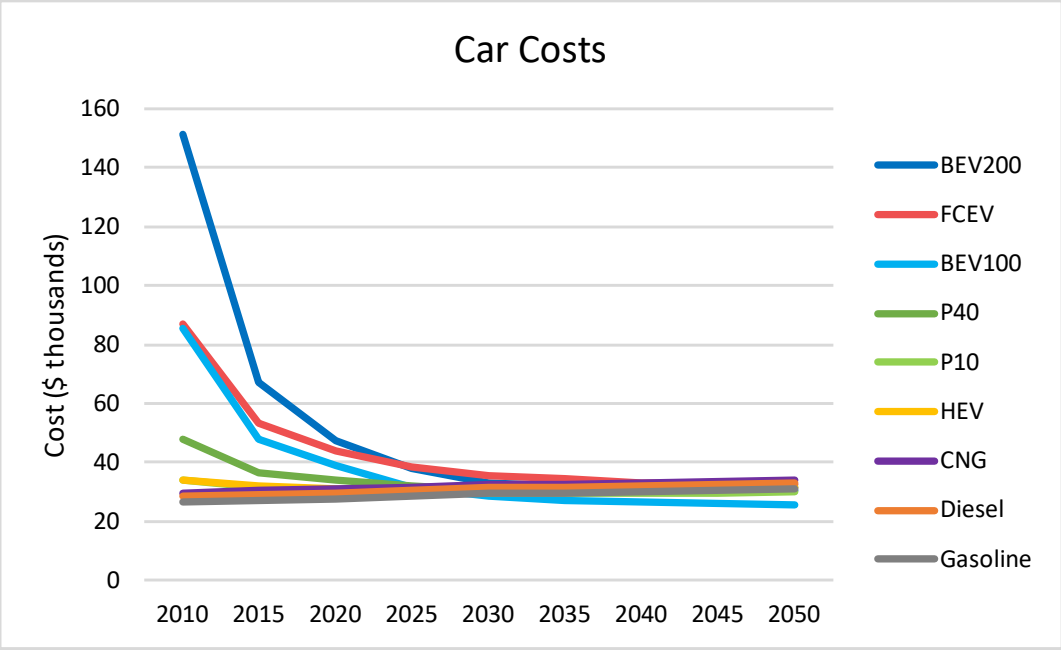
- Truck Choice Model (TCM)
  - Input: vehicle, fuel parameters ($, mpg, CI, etc.)
  - Purchase decision factors (risk, refueling inconvenience, model availability, incentives, etc.)
  - Truck Outputs: sales shares through 2050 based on fleet purchase decisions
- Transportation Transitions Model (TTM)
  - Stock turnover model (LDVs and trucks)
  - Input: vehicle, fuel parameters ($, mpg, CI, etc.)
  - Output: Fleet stock, vehicle costs, fuel costs, GHG emissions (year by year through 2050)

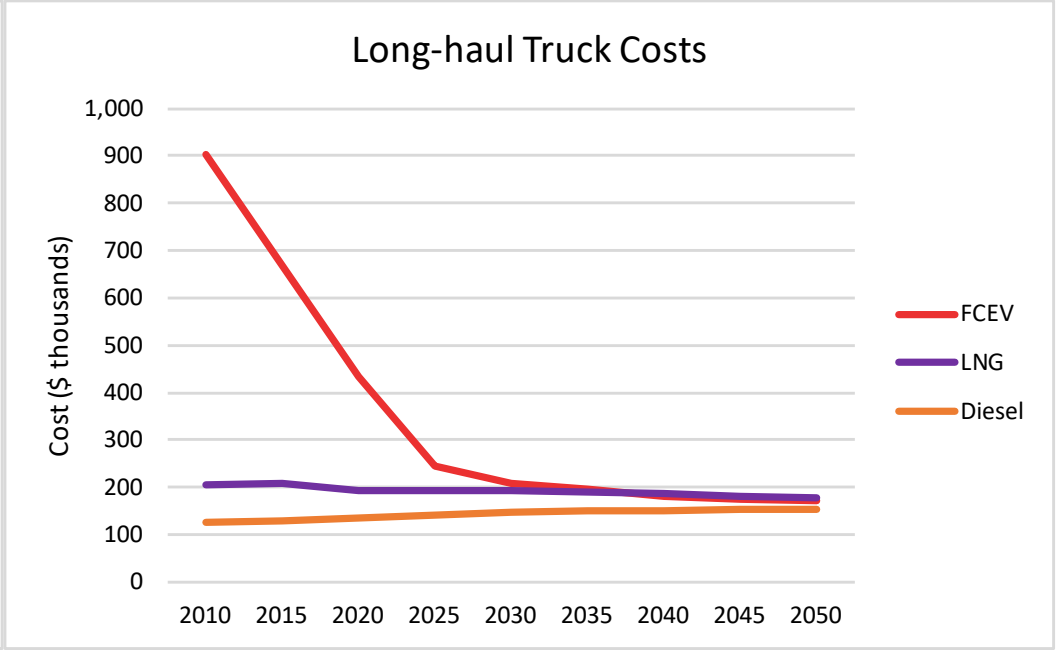
TTM Modeling System



Key input: vehicle costs

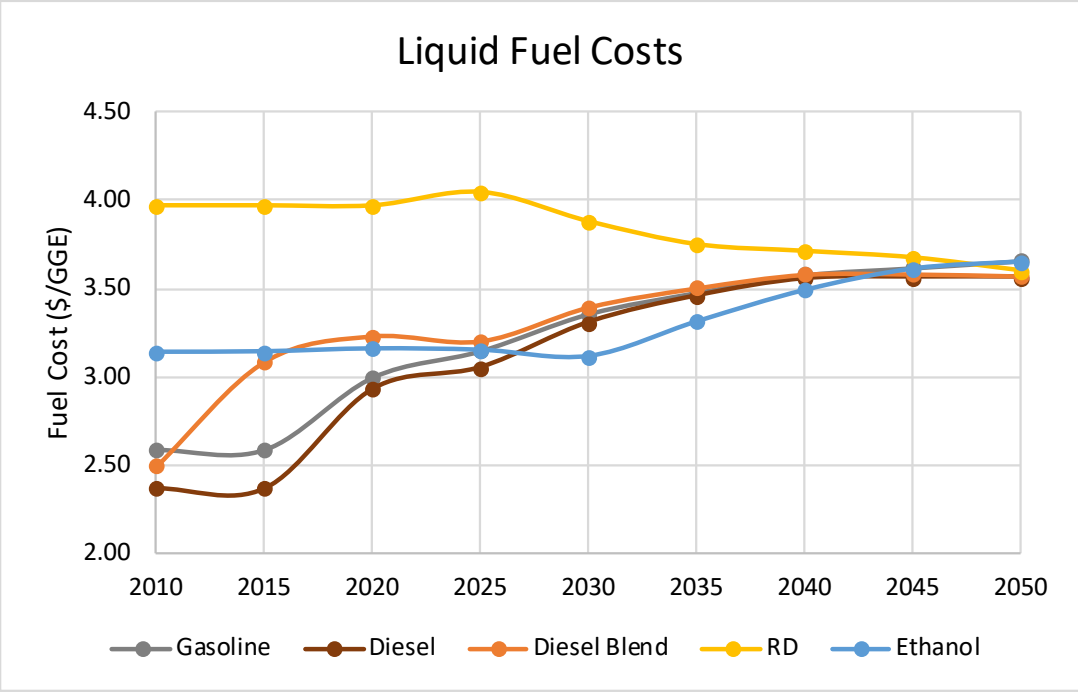
- Glider + components (engine, battery, fuel cell, power electronics, fuel storage, etc.)
- Component cost curves that (generally) decrease with time due to volume sales, learning

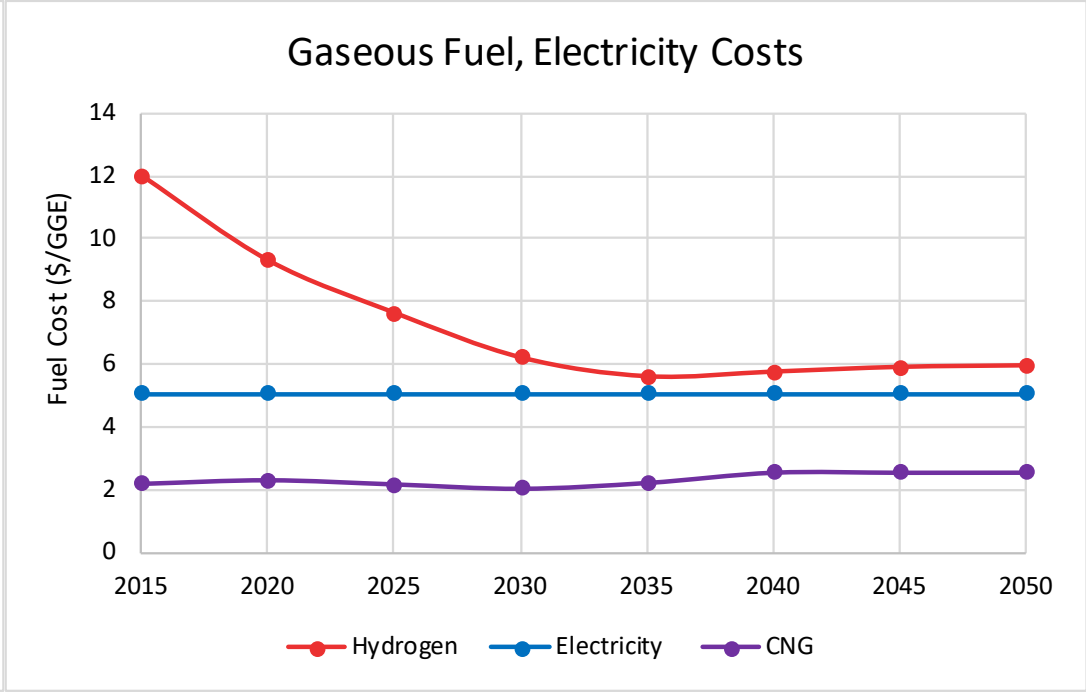




Key input: fuel costs

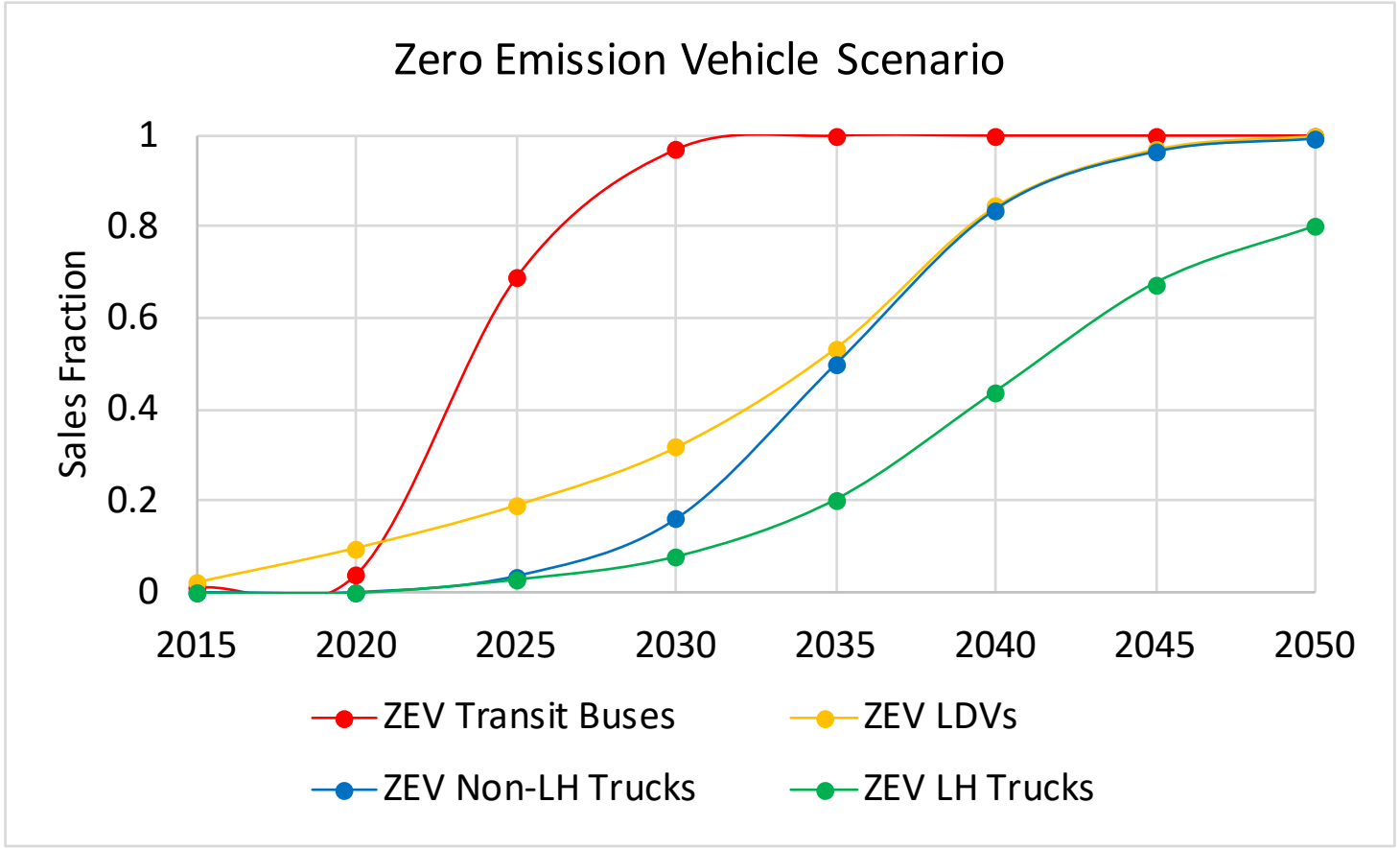
- Fuel costs are based on a detailed assessment of technology costs, feedstocks, electricity generation evolution, and oil price evolution
- Ultimately we used some guiding principles, such as keeping diesel fuel at $3.50 throughout the projection period, bringing H2 costs down as scale increases, assuming biofuel technology costs decline, etc. We do sensitivity analysis to address uncertainties in this regard





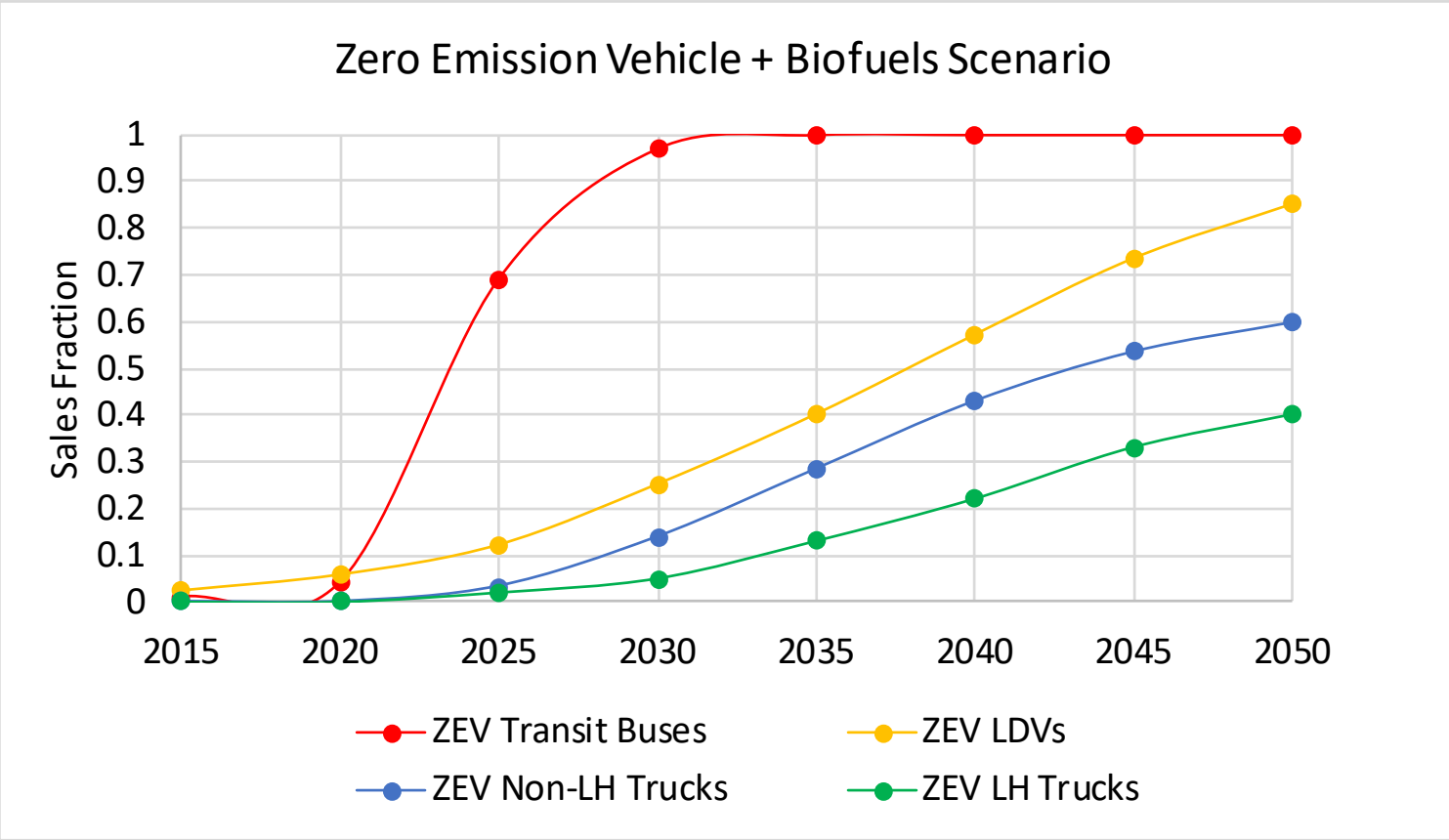
ZEV scenario sales of ZEVs show a range of future by vehicle type

- Transit Buses reach 100% ZEV market share by 2030
- Only long-haul heavy-duty trucks do not reach 100% ZEV by 2050



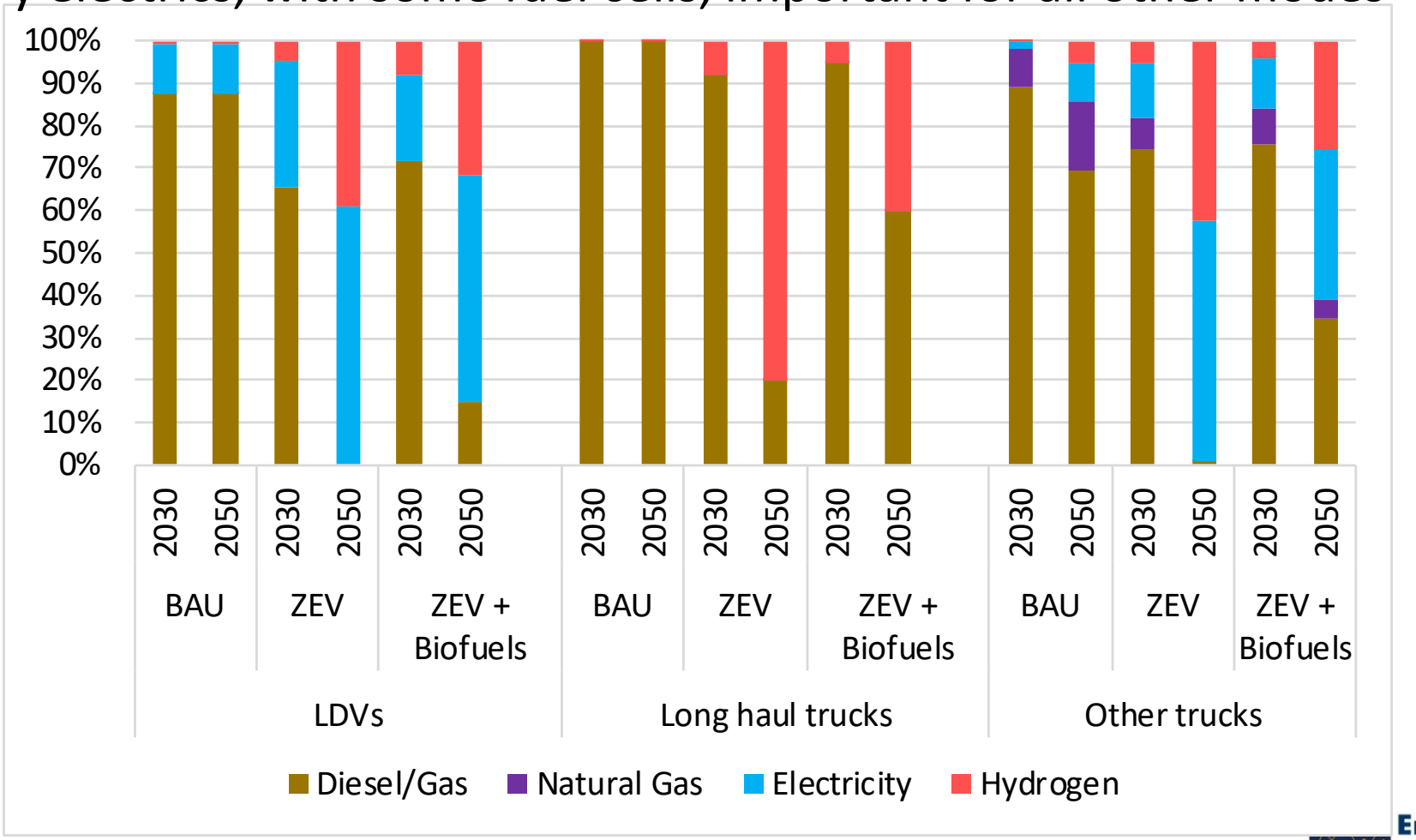
ZEV Vehicle Sales are lower in the ZEV + Biofuels scenario

- Only transit buses reach 100% ZEV
- Long-haul trucks reach 40%



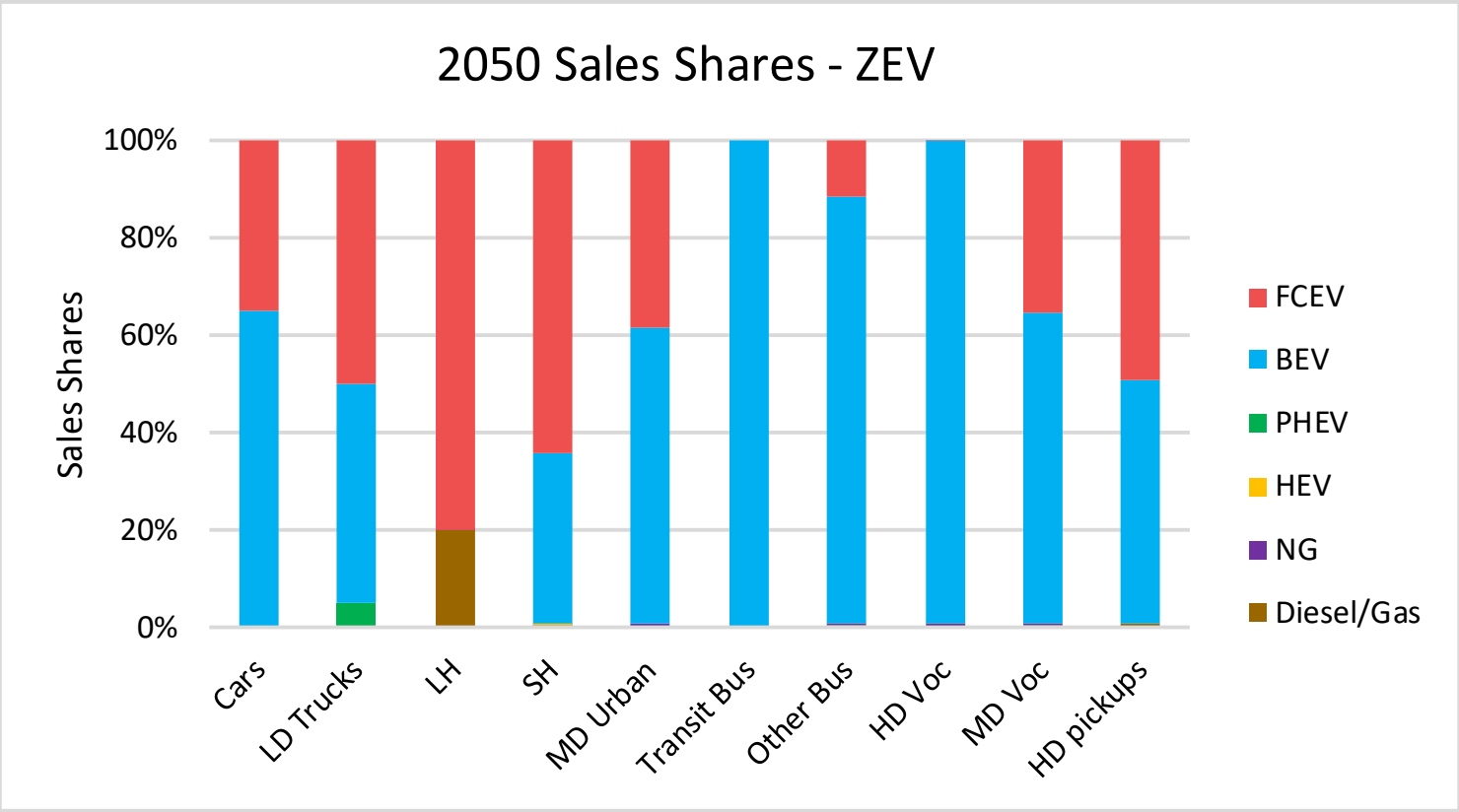
Sales share evolution including technologies

- Hydrogen/fuel cells come to dominate long-haul trucking
- Battery electrics, with some fuel cells, important for all other modes



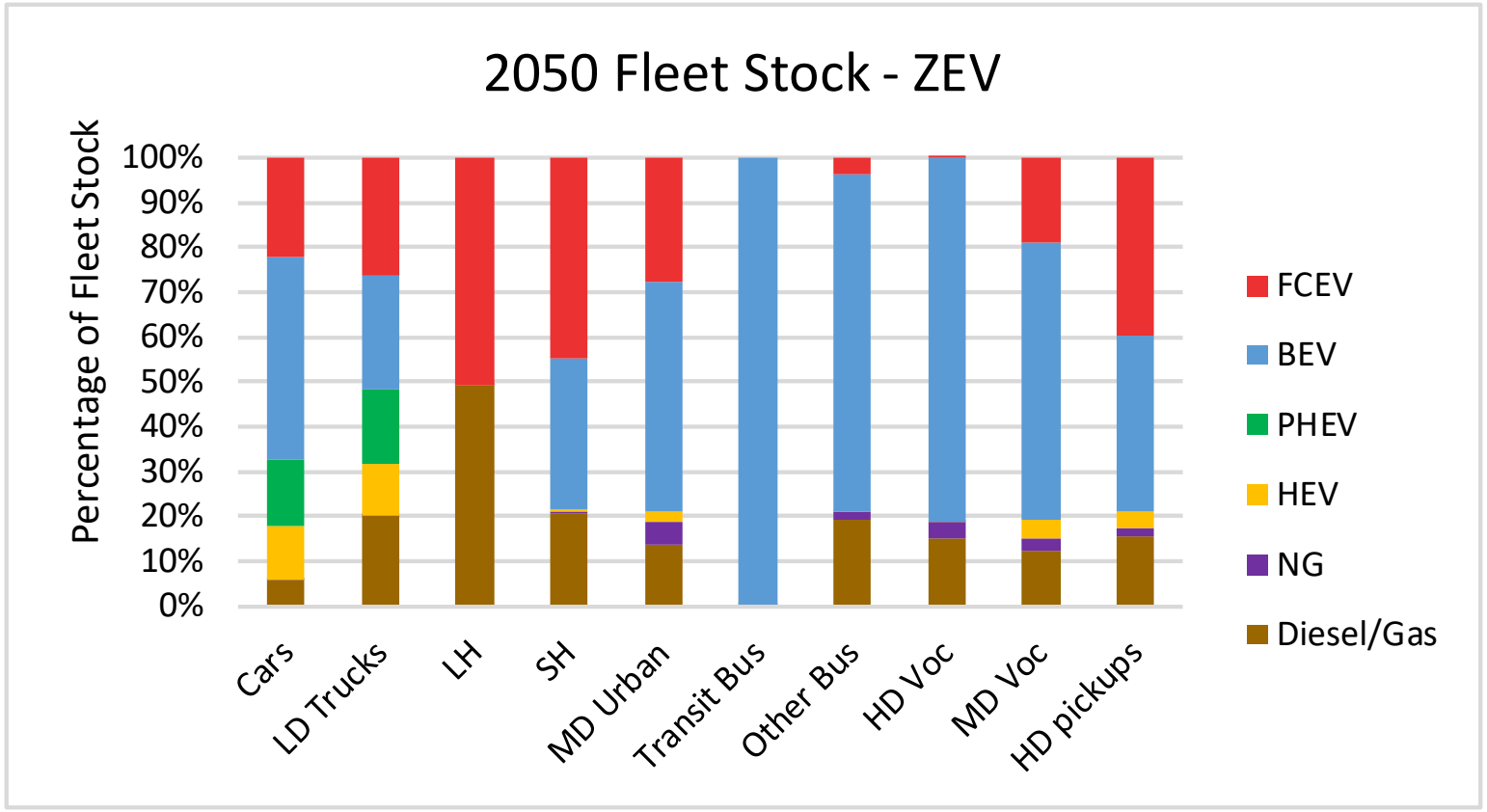
ZEV Scenario 2050 sales are dominated by two technologies

- Showing technology shares in 2050 for 10 different vehicle types reveals a wide range of BEV vs FCEV penetration.
- This reflects the cost and applicability of technologies in different applications.



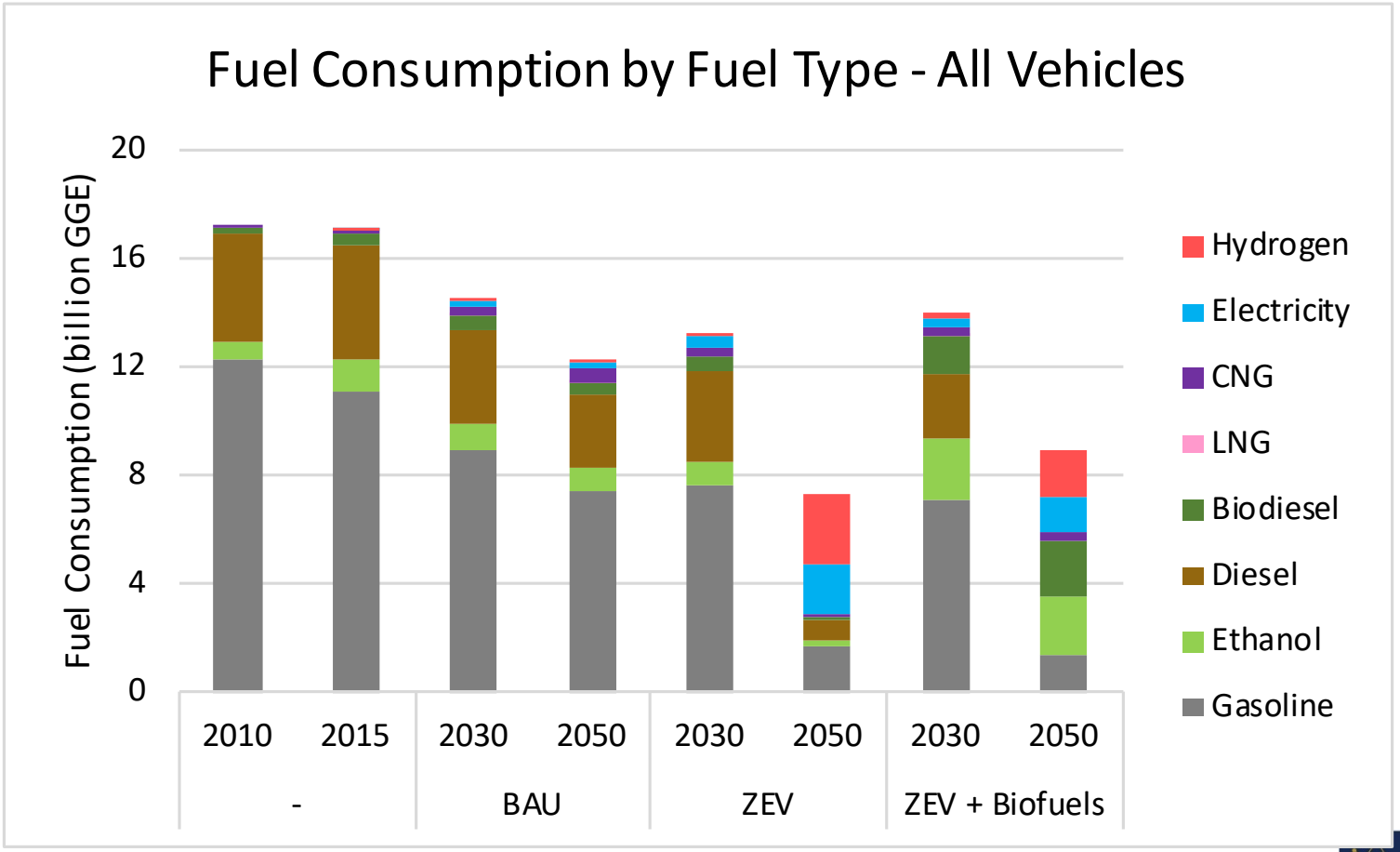
ZEV Scenario 2050 Fleet Stock Composition

- Given the lag time in stock turnover, there is still 20% or more diesel/gasoline vehicles remaining in most vehicle types (50% for long haul).
- These ICEs would be fully phased out by 2060



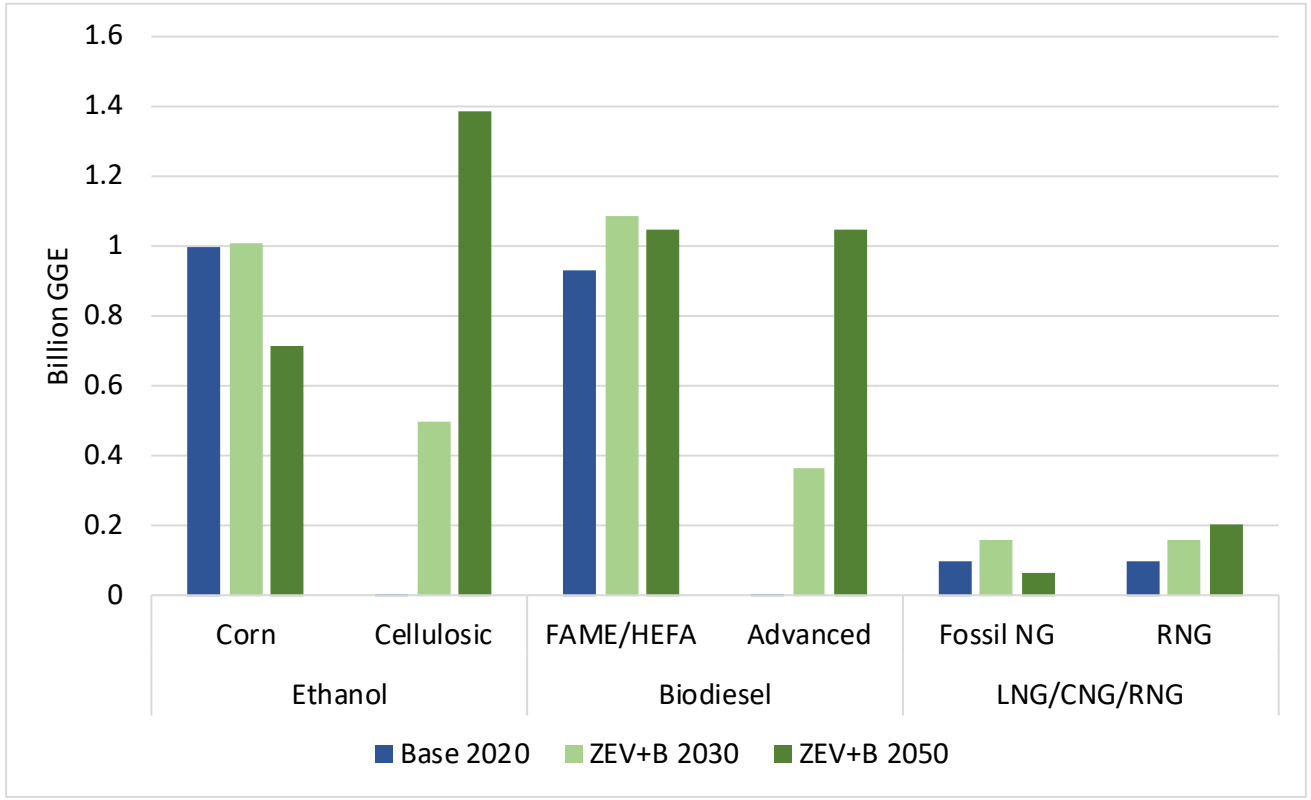
Resulting fuel use is very different in 2050, in ZEV and ZEV+B

- In ZEV Scenario, more than 50% reduction in fuel use, with hydrogen the top fuel
- In ZEV+B, biofuels reach 50% of road transportation fuel use by 2050



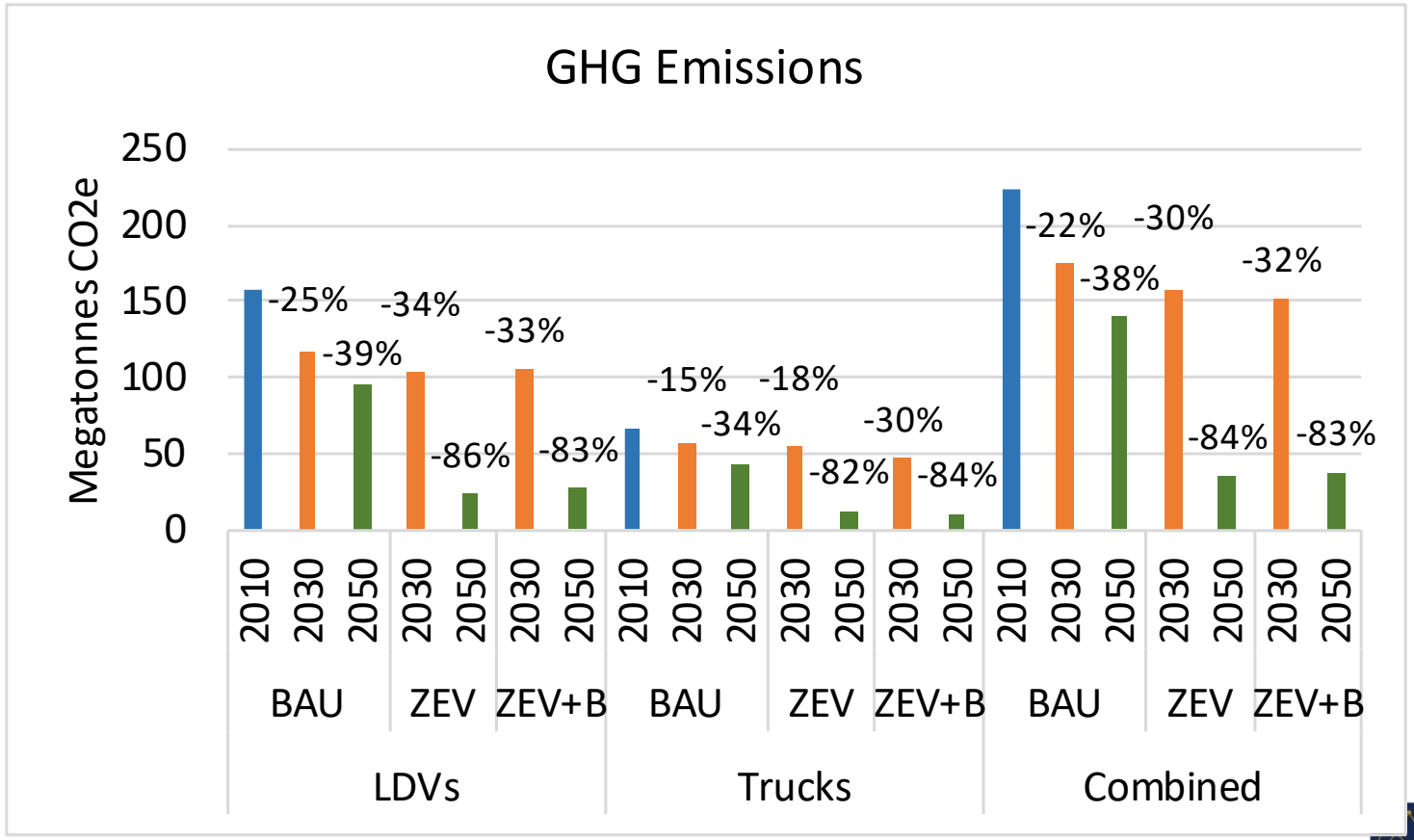
In ZEV+B, advanced biofuel use rises rapidly after 2030

- Cellulosic based biofuels grow rapidly after 2030. These are needed to reach GHG targets but may be expensive and the sourcing, feedstock, net carbon intensity aspects need much further study.
- Corn ethanol and oil-based HEFA type biodiesel production maintain current production levels; CI's improve somewhat over time.



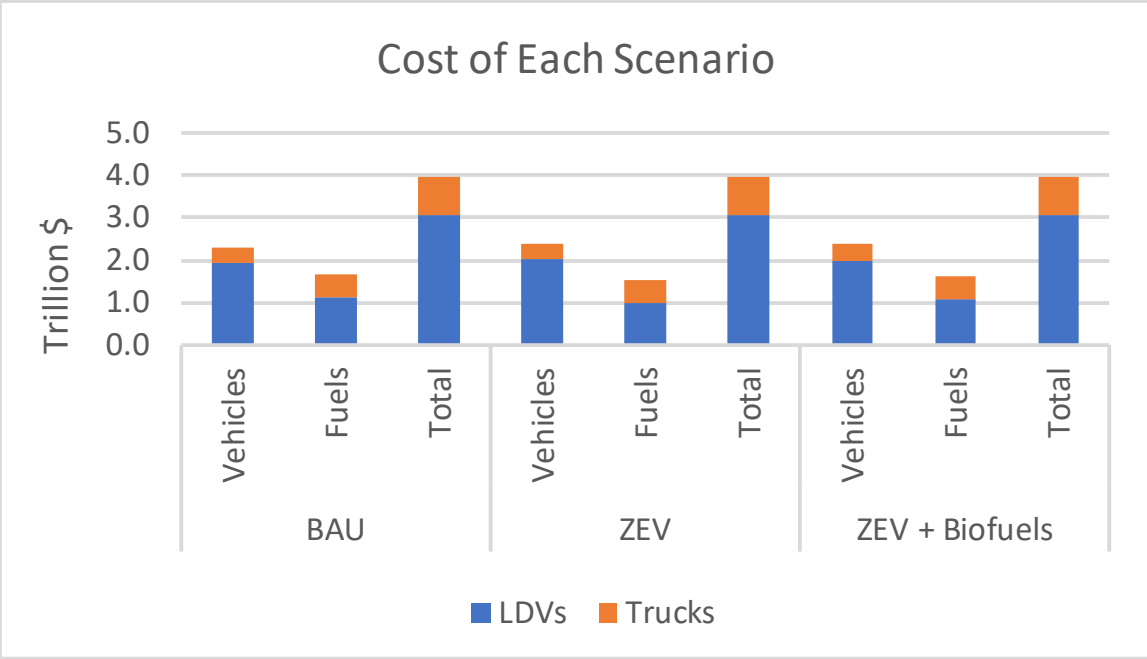
The result: CO2e emissions hit the target

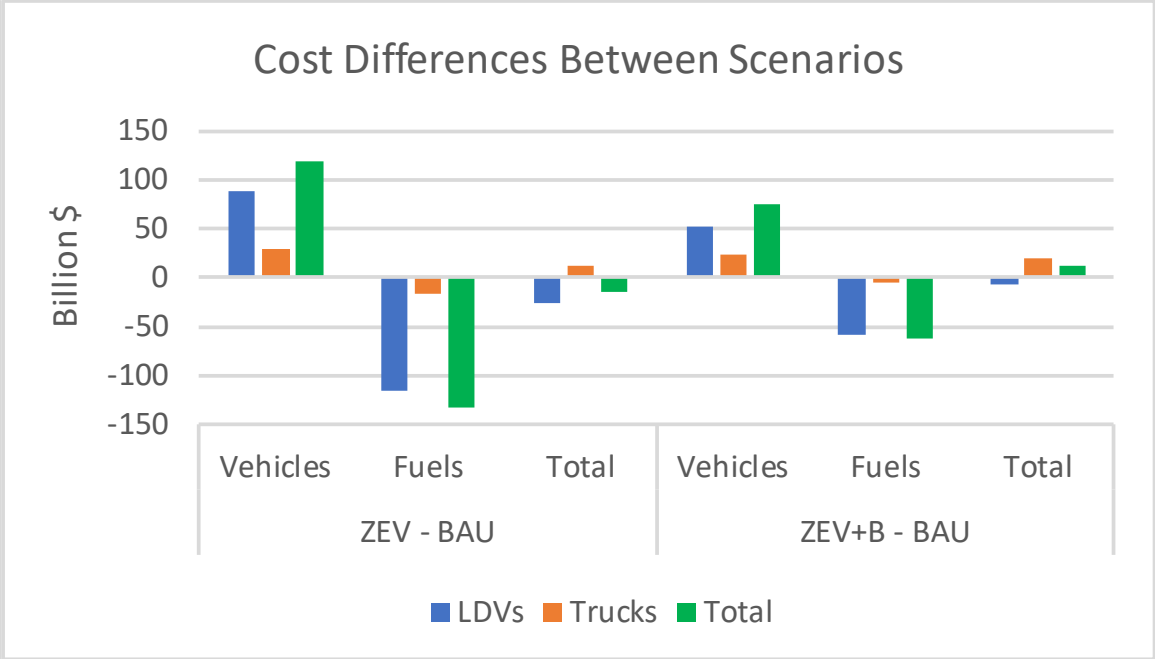
- More than an 80% reduction for LDVs and for trucks relative to 2010, in both scenarios
- Our accounting is pegged primarily to 2010, though we surpass 80% to achieve roughly 80% reductions compared to 1990.



Summary of cost results

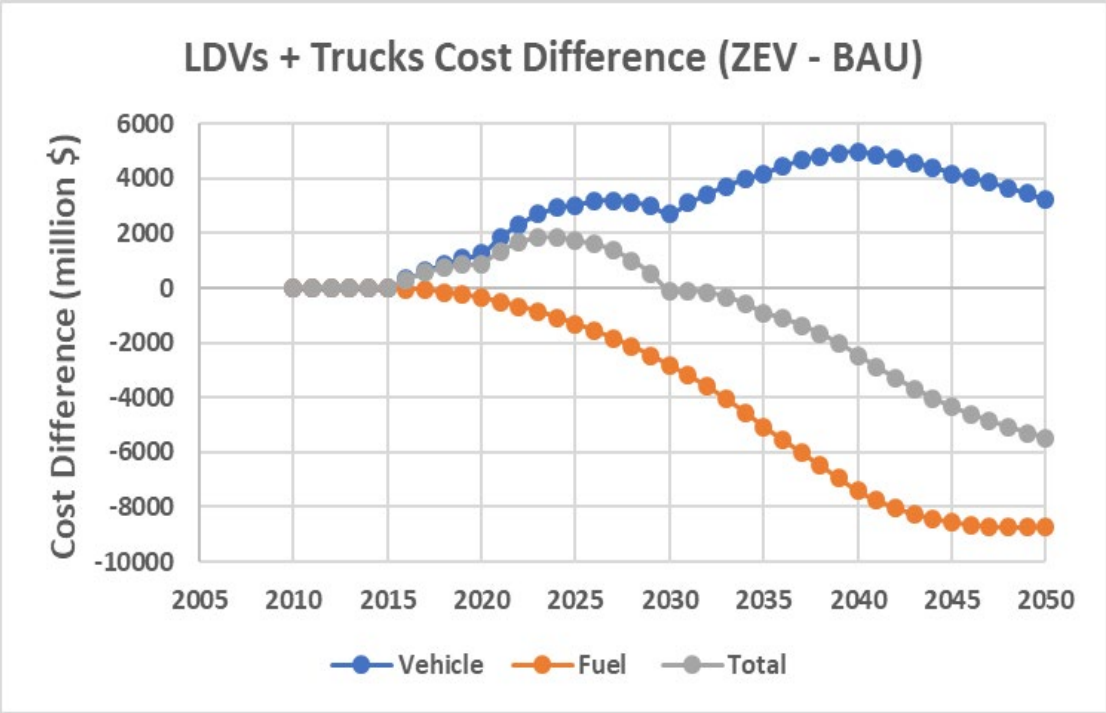
- At first glance, the three scenarios have almost identical costs: $4 Trillion (2015-2050)
- However, drilling down reveals large differences at the level of vehicles vs fuels, cars vs trucks, differences across scenarios, etc.
- There is a general tendency for fuel savings to offset (and pay for) higher vehicle costs (see next slide)

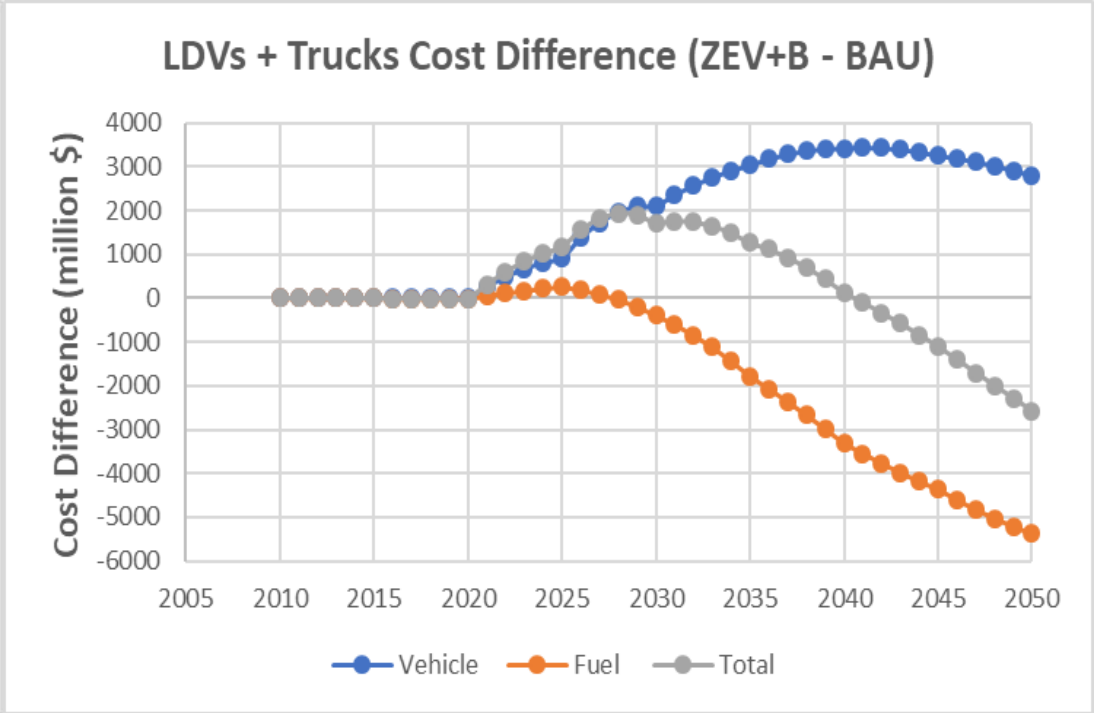




Cost Evolution, ZEV and ZEV+B vs BAU scenario

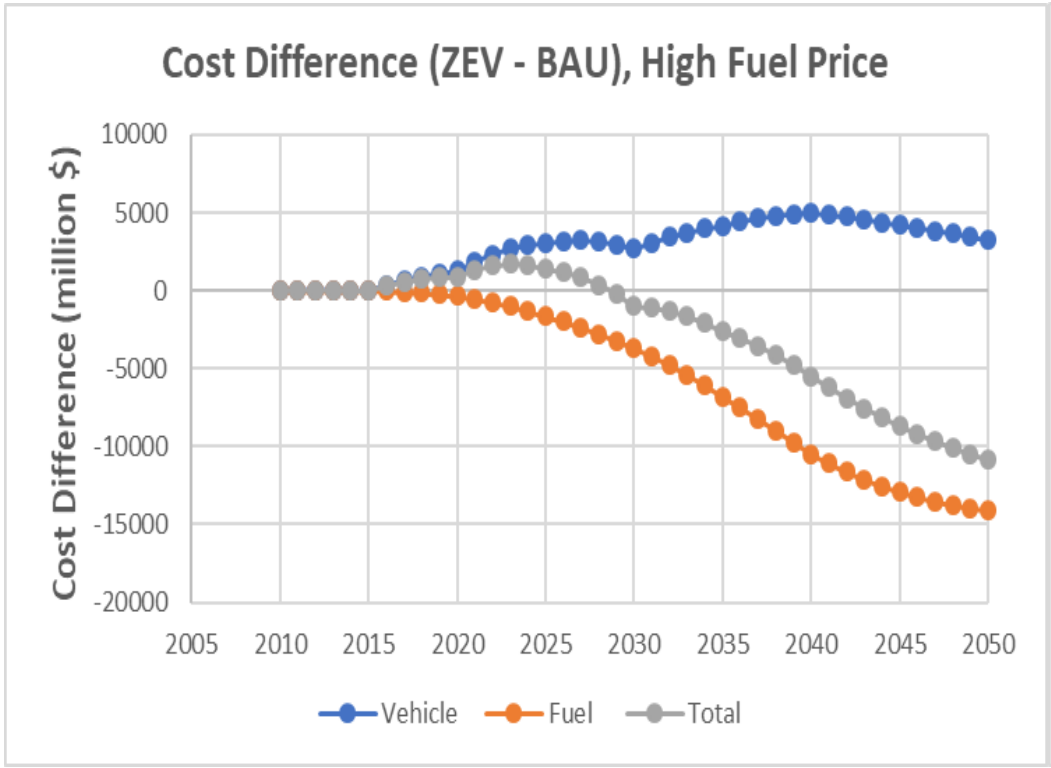
- Our cost accounting is aggregate, adding all vehicle purchase and refueling costs across all vehicles/fuel in each year.
- In the aggregate, vehicle costs for ZEVs remain above gasoline/diesel through 2050, while fuel costs go lower. The net effect for ZEV scenario is higher costs until 2030, then lower; for ZEV+B the breakeven point is 2040.

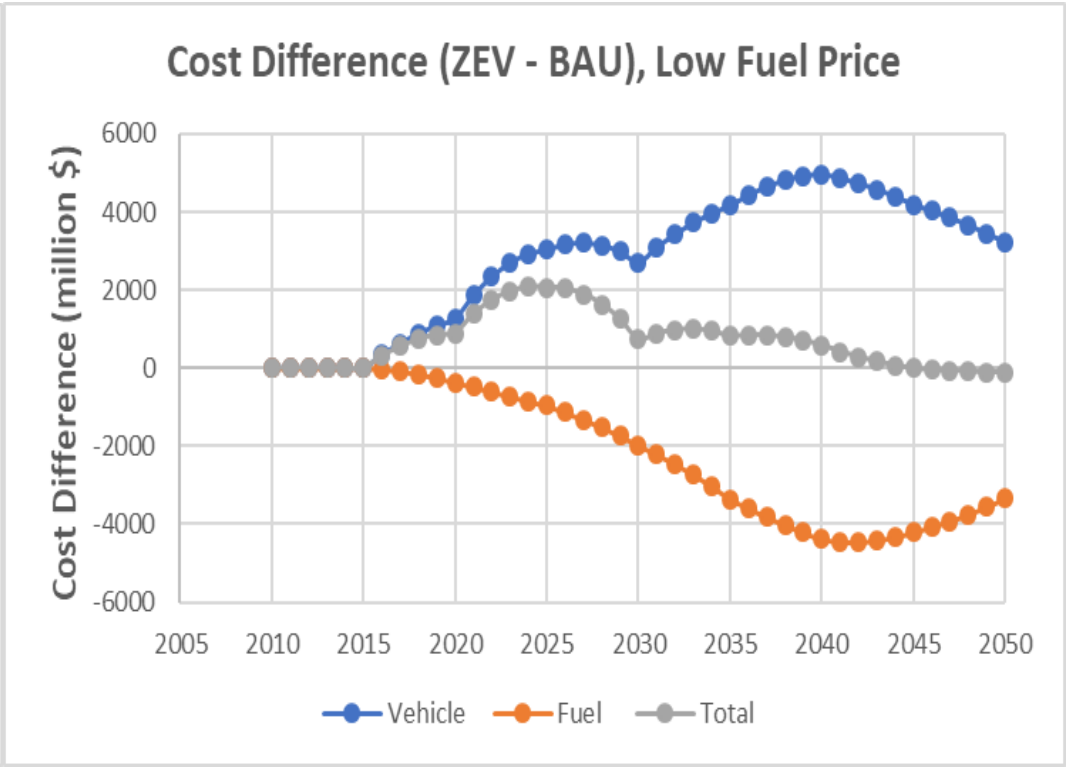




Assumptions matter: Cost Difference: High (+20%), Low (-20%) Fossil Fuel Price

- We have done a number of sensitivity cases, explained in the report.
- In this one, we vary gasoline/diesel price. A higher price moves the breakeven point up to about 2028; a lower price moves it back past 2040.





Some policy implications

- Although we did not conduct a detailed policy analysis in this study, several policy implications are apparent, particularly related to costs and incentives:
  - There is an ongoing need for policy support, particularly to address the vehicle price gap between ZEV and conventional trucks.
  - These incentive policies will be more easily phased out once per-vehicle costs decline sufficiently to fully establish the market, but it is difficult to predict when that will be.
  - If battery technology advances sufficiently to allow penetration into longer-range truck applications, that could fundamentally change the expected vehicle portfolio and obviate the need for more expensive fuel cell trucks.
  - Without substantial penetration of ZEV technology into the truck sector, emissions reductions will likely have to be driven by biofuels, which may be challenging due to limited sustainable supply and would likely result in higher fuel costs.

Conclusions

- There are many conclusions, most have been covered but we highlight a few here:
  - In the ZEV scenario, attaining an 80% reduction in GHGs is feasible but (especially for trucks) will require a particularly rapid ramp-up in sales after 2025.
  - Achieving deep GHG reductions in the ZEV scenario requires that energy for these vehicles, namely hydrogen and electricity, must eventually come from very low GHG sources.
  - In the ZEV+B scenario will need very high, possibly infeasible or unsustainable, levels of advanced, very low-carbon biofuel use. A transition will be needed from today's dominant biofuels, from grains and oils, to predominantly cellulosic biomass-based fuels.
  - The cumulative cost of the ZEV scenario from 2015 to 2050 for vehicles and fuels, aggregated across LDVs and trucks, is not significantly different than the cost of the BAU scenario. Higher vehicle costs are repaid through lower energy costs for electric compared to conventional vehicles. After 2030, these cost savings more than offset the higher capital costs.
  - However, for some specific vehicle types (such as long-haul trucks) that are dominated by fuel cell vehicles, there are no fuel cost savings, so the overall costs are higher than the BAU.
  - In our main scenarios, we estimate that the overall cost would be higher for the ZEV+B than the ZEV scenario, due to expected high advanced biofuel costs.
  - However, the costs of each scenario vary substantially depending on a range of assumptions about technologies and fuels, particularly future petroleum, hydrogen, and biofuel prices. We explore this through a sensitivity analysis.
- More research is needed! Such as on the dynamics of ramping up ZEV production, how to encourage consumers and businesses to adopt these vehicles in large numbers, and the implications of relying on advanced biofuels as part of the mix
- STEPS/Energy Futures is working on additional reports on truck choice modeling and a technology cost report. A future study of a carbon neutral 2045 scenario may also be developed.

Thank You

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Report available here:

https://www.ucdavis.edu/news/californias-transition-low-carbon-road-transportation/