DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Understanding California's Transition to ZEV (Zero Emission Vehicle) Trucks

To develop a new, prototype truck decision choice spreadsheet model that can be used to simulate the decision behavior of fleets and other truck purchasers.

Planning, Policy, and Programming

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Project Title:
Understanding California's Transition to ZEV (Zero Emission Vehicle) Trucks

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WHAT IS THE NEED?

There have been numerous studies that have looked at the potential for California to make significant reductions in GHG (greenhouse gas) emissions and achieve the 80% GHG reduction target. These studies all indicate that meeting these GHG targets is potentially feasible at reasonable costs and that mitigation will come from a variety of strategies (including efficiency, new advanced technologies, and low-carbon energy sources) across a variety of energy supply and end-use sectors. They all point to transportation as a key source of GHG emissions and one of the most important sectors in which to make reductions. These studies, along with studies that looked solely at the transportation sector as a source of GHG reductions, focus heavily on the light-duty sector because of its importance in California (nearly 2/3 of fuel use and GHG emissions come from cars and light trucks) and see the importance of vehicle efficiency as well as alternative fuels (biofuels, electricity, and hydrogen) to lowering emissions. These studies represent a variety of modeling methods and approaches, but all suffer from the same lack of data and simplified representation of the non-light-duty transportation sectors.

WHAT WAS OUR GOAL?

The goal of this project was to develop sustainable freight data and a truck purchase decision choice tool (prototype) to better understand how California's fleets will transition to low carbon technologies and fuels, especially zero-emission technologies such as electric and fuel cell trucks. We developed data comparing vehicle/technology performance, vehicle capital and operating costs, mileage and performance requirements, and other important purchase decision factors for different types of trucks and fleets, extending what is available for example in EMFAC (Emission Factors) model and VISION. (The EMFAC model is used by the California Air Resources Board (CARB) to assess emissions from on-road vehicles including cars, trucks, and buses in California, and to support CARB's regulatory and air quality planning efforts to meet the Federal Highway Administration's transportation planning requirements. The VISION model provides estimates of the potential energy use, oil use, and carbon emission impacts to the year 2100 of advanced light- and heavy-duty highway vehicle technologies and alternative fuels). The project developed a prototype decision choice model for alternative fueled trucks to assess the impacts of various attributes on the purchase decisions of various types of fleets, and create technology adoption scenarios. Truck types included heavy-duty pickups and vans, medium-duty urban, medium-duty vocational, urban buses, other buses, heavy-duty vocational, short haul, and long haul. For each truck type we assumed 3 fleet categories – early adopter, late adopter, and in-between. The early adopter category included fleets that were more likely to purchase new technology trucks. Researchers investigated critical factors that affect fleet purchase decisions, reasonable adoption rates for new technologies, and the effect of infrastructure deployment on purchases.

WHAT DID WE DO?

Task 1: Develop a fuel truck technology, cost and fuel consumption model including vehicle choice and sales/stock modeling components:

This task included a detailed literature review of existing truck models that include truck energy use projections, as well as costs for conventional and alternative fueled trucks, key components such as batteries and fuel cells, and emissions control technologies.

Task 2: Acquire data on truck fleets and truck purchase decision factors:

We leveraged existing data sets (such as CARB's VISION 2.0 model which includes EMFAC data) to identify the population and average mileage for California trucks of different sizes as well as sizes of different fleets. We conducted a series of interviews and organized a Truck Choice Workshop with fleet managers, GMOs, and regulatory agencies to better understand the critical factors influencing decisions to purchase trucks.

Task 3: Develop truck discrete choice framework:

We created a decision choice model for advanced technology trucks that feeds into the model described for Task 1. The model is similar to those used for LDVs (such as ORNL's LAVE-TRANS). This work is based upon a nested multinomial logit (NMNL) framework which segments discrete choices among several layers and including groupings of similar technologies into "nests". The weighted decision factors from Task 2 along with information about truck costs, risks, infrastructure, and policy will provide the inputs for decisions. Truck purchase probabilities can be computed based upon utility maximization and random variation in decision-maker preferences.

Task 4: Create future scenarios to estimate GHG emissions and evaluate effects of policy levers:

We used our modeling system to estimate GHG emissions for time periods through 2050 for a variety of California scenarios based on variation of the decision factors. In particular we evaluated the effect, timing and cost of various factors that influence the transitions to lower carbon technologies. The scenarios included:

- A business-as-usual (BAU) scenario with truck sales likely calibrated to Vision projections, though also linked to the choice model.
- A ZEV mandate scenario requiring all truck types to reach 25% ZEVs by 2050. The ZEV truck could be either battery electric or fuel cell. This is ZEV scenario 1a.
- A ZEV mandate scenario requiring all truck types to reach 25% ZEVs by 2050. This scenario assumes all technologies have the same refueling penalty as diesel trucks (i.e. low refueling inconvenience). This is ZEV scenario 1b.
- A ZEV mandate scenario requiring all truck types to reach 50% ZEVs by 2050. The ZEV truck could be either battery electric or fuel cell. This is ZEV scenario 2.

Task 5: Development of analysis reports and documentation, presentation materials, development of a UC Davis web page to house the outputs and related materials, and provision of the modeling system to interested parties within Caltrans and other agencies (CARB and CEC).

WHAT WAS THE OUTCOME?

In general, the BAU scenario market shares change relatively little through 2040 and include only very modest penetrations of new technologies such as battery electric vehicles or fuel cell vehicles, and only toward the end of the timeframe, mostly in the early adopter fleet category.

The ZEV scenarios were explored to understand the need for incentive funding that might be needed to overcome various disincentives of ZEV technologies, such as the higher capital cost, perceived uncertainty toward new technologies, refueling inconvenience, and initial low model availability.

Different ZEV technologies were used to meet the mandate for differing truck types. For example, fuel cells met the entire mandate for long haul trucks because our model does not include battery electric trucks in that truck type due to weight considerations. Battery electric and fuel cell trucks reached similar market shares in short haul trucks, but battery electric trucks dominated the ZEV market share in medium-duty vocational and transit buses because the capital costs of battery electric vehicles are lower than the cost of fuel cells in those truck types.

The necessary incentive per vehicle starts as a significant percentage of the capital cost but drops to a small fraction of that cost in most cases, as market shares of ZEV technologies rise toward the target. Short haul trucks and urban buses required no incentives toward 2050 to meet the mandate for scenario 1b (with refueling inconvenience equal to diesel refueling inconvenience).

The total incentives required to meet even the 25% mandate for all truck types are quite high ($7.7 and $9.6 billion for the low refueling inconvenience and normal refueling inconvenience cases, respectively). For certain truck types, the total incentives necessary are much more modest. In scenario 1b transit buses require $53 million, medium-duty vocational trucks require $165 million, and short haul trucks require $116 million from 2030 – 2050.

This study has found that:

- There are a range of factors that truck operators and fleets consider when purchasing new trucks and that may affect their choices involving new drivetrain and fuel technologies
- The high initial cost, low range, and uncertainty of ZEV technologies appear to severely limit

their marketability in the near term.
- Over time this situation should improve as these attributes improve, such as through battery cost reduction and better availability of hydrogen for fuel cell trucks.

Potential future work that could improve the results includes:
- Add plug-in hybrid vehicle technology. Plug-in hybrids could play an important role for some truck types.
- Improve capital cost model. The present model sums component cost but may underestimate vehicle cost during early market penetration due to lack of technology development and engineering design costs.
- Better understand decision choice factors. The equations used to model certain non-monetary factors such as risk and refueling inconvenience have significant uncertainties. Further discussions with fleet managers could allow us to better model those factors.
- Include additional factors. We may wish to include additional factors such as payload reduction due to the weight of new technologies.
- Include lifecycle cost benefits. We presently do not include societal benefits such as lowered emissions. While these benefits would have little or no impact on the actual fleet purchase decisions, their value could be significant.

WHAT IS THE BENEFIT?

GHG reductions in the trucking sector are critical to meeting climate change goals. Understanding how this sector could realistically transition to low carbon technologies and fuels requires a model that incorporates real world purchase decisions. The model allows us to investigate various paths to a low carbon trucking future through a better characterization of trucking fleets and a real world decision choice model based on factors affecting such decisions. The model helps to assess the effect of various policy levers such as incentives or subsidies. These policy levers may be critical to the early adoption of new technologies such as electric and fuel cell drive trains.

LEARN MORE

https://ncst.ucdavis.edu/project/truck-choice-modeling-understanding-californias-transition-to-zev-trucks-taking-into-account-truck-technologies-costs-and-fleet-decision-behavior/

IMAGES

Scenario	GHG reductions (%) from 2010 by 2050
BAU	10
ZEV scenario 1	22
ZEV scenario 1 with low refueling inconvenience	45
ZEV scenario 2	46

Figure 1: Greenhouse gas emissions reductions from 2010 by 2050