

Sustainable Transportation Energy Pathways (STEPS)

HD Truck Technology Transitions: Comparing an Energy Model with a Choice Model

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Transition Models for Transport Decarbonization

- **Presentation Goal:**
  - To explore the transition to a lower-carbon HDV sector, with emphasis on vehicle efficiency, advanced technologies, and alternative fuels
  - To understand how different modeling approaches can help us answer different questions about this transition
- **Methods:**
  - Use different models of different types to explore the transition from conventional HDV vehicles to low-carbon vehicles and fuels
    - **Truck Choice Model** – Discrete choice simulation
    - **CA-TIMES** – Energy system optimization model

Truck Choice Model

- Researchers: Marshall Miller, Qian Wang, Lew Fulton
- **Core model**: Nested multinomial logit (NMNL) discrete choice model
- Brings in three important additional behavioral elements relative to optimization (→ diversity in tech. adoption)
  - Consumer heterogeneity (i.e. segmentation)
  - Variation in preferences (probability distribution)
  - Adoption is driven by overall generalized cost
    - Capital and operating costs (over planning horizon)
    - Inclusion of non-monetary utility factors (besides costs)
      - Environmental perception
      - Uncertainty (Risk)
      - Model Availability
      - Vehicle Range
      - Refueling Time
      - Station Availability

} Disutility due to lost driver time for finding stations and fueling vehicle

CA-TIMES Energy System Model

- Students: Kalai Ramea, Saleh Zakerinia
- **Core model**: Linear optimization (cost minimization) of investment and operating costs of entire energy system from 2010-2050
    - primary resources
    - conversion technologies (fuels and electricity production)
    - end-use technologies (vehicles, appliances)
  - Minimize cost of building and operating energy system to meet demand for energy services
    - Capital Cost
    - Operating costs (fuel use, maintenance)
    - Incentives
    - Carbon price/constraints
  - Global decision-maker
  - Constraints are critical to shaping technology adoption
    - Carbon caps
    - Policy constraints (CAFE, ZEV mandate, RPS)

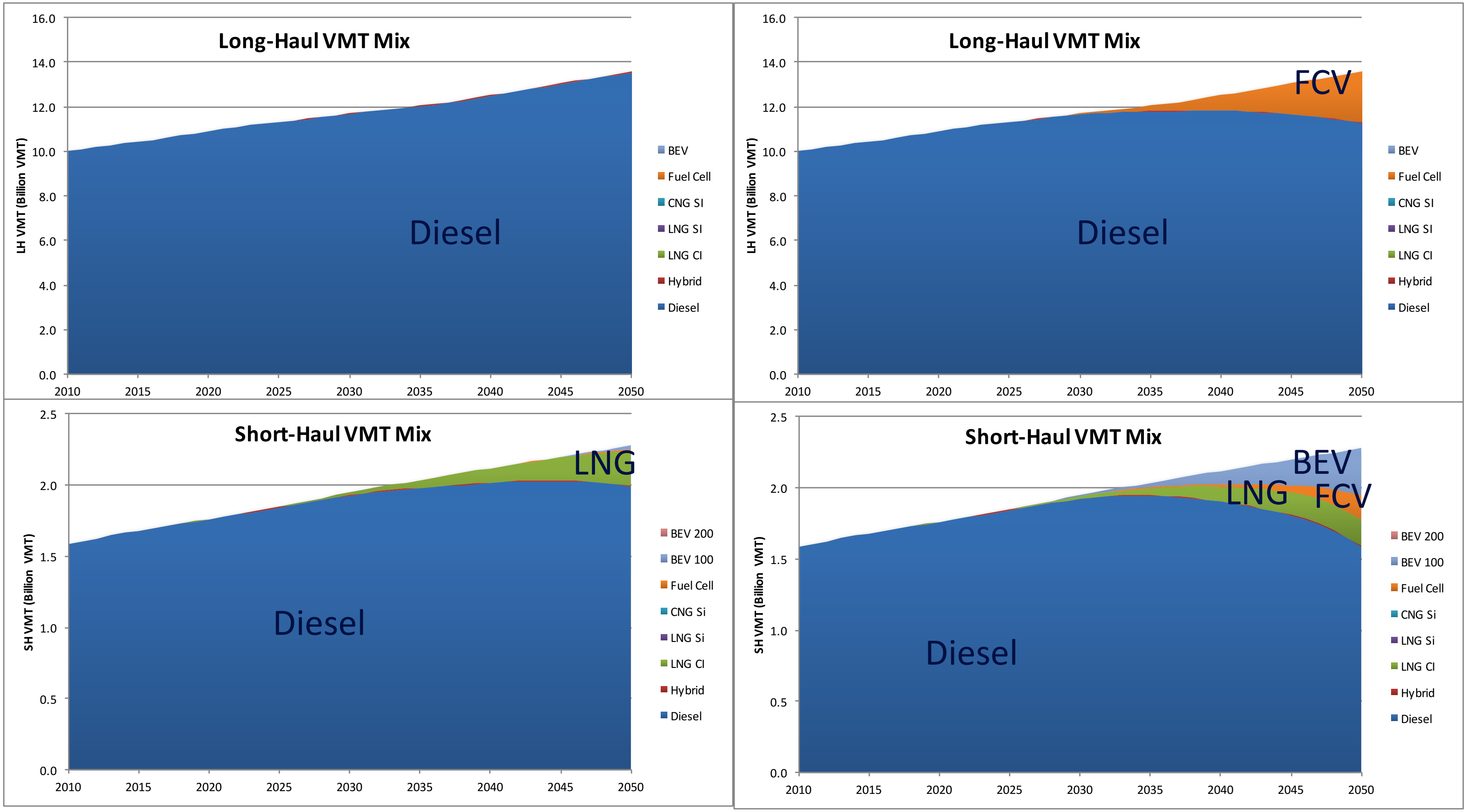
Choice model vs Optimization

Attribute	Choice Model	Optimization Model
Focus of Analysis	Vehicle adoption behavior	Energy system linkages – vehicle adoption coupled with upstream supply infrastructure and resources
Representation of decision-maker(s)	Consumer heterogeneity – many individuals maximizing utility	Global decision-maker - a single decision-maker designing the system
Decision factors	Utility, including non-monetary factors	Hybrid, primarily economic cost factors (coupled with implications in other sectors) with high discount rates are used to approximate non-monetary factors*
Results	Probabilistic purchase behavior	Often see “winner-take-all” behavior (one technology is the lowest cost)

* We have included non-monetary factors in the decision-making for LDV purchases (COCHIN)

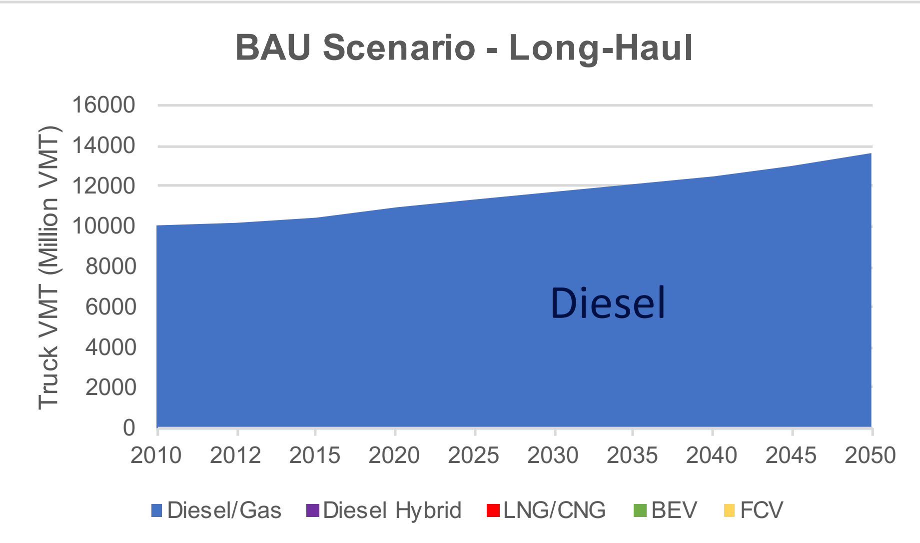
Truck Choice Model Results

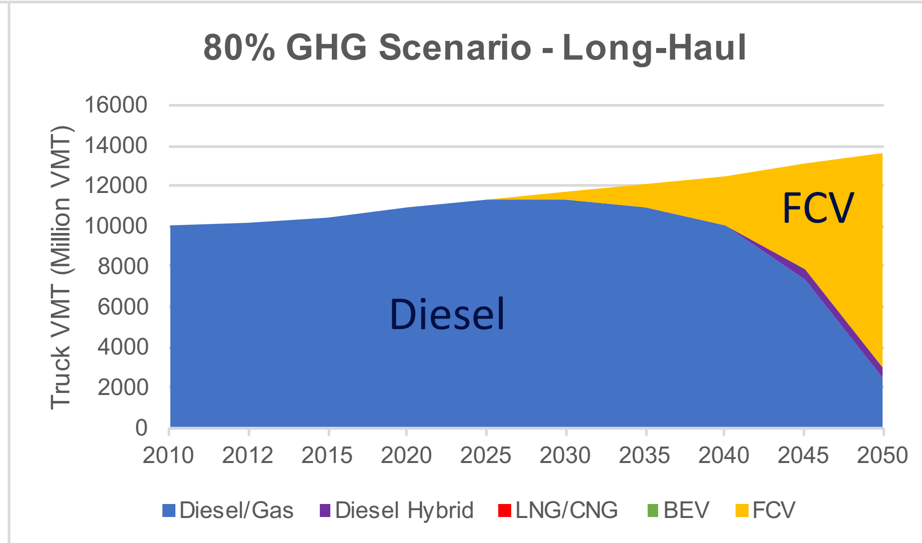
Scenarios: (L) BAU, (R) HDV ZEV mandate scenario (25% by 2050) includes carbon tax ($150/tonne by 2050)

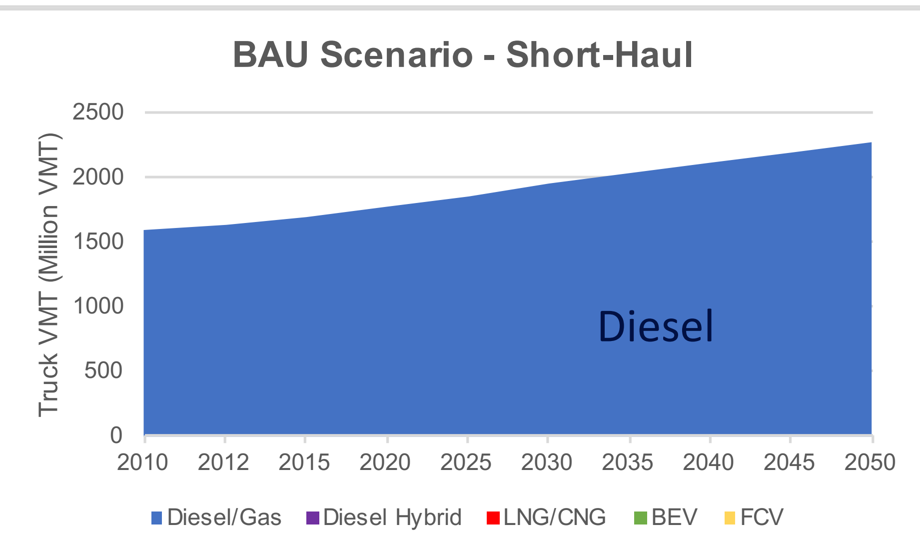


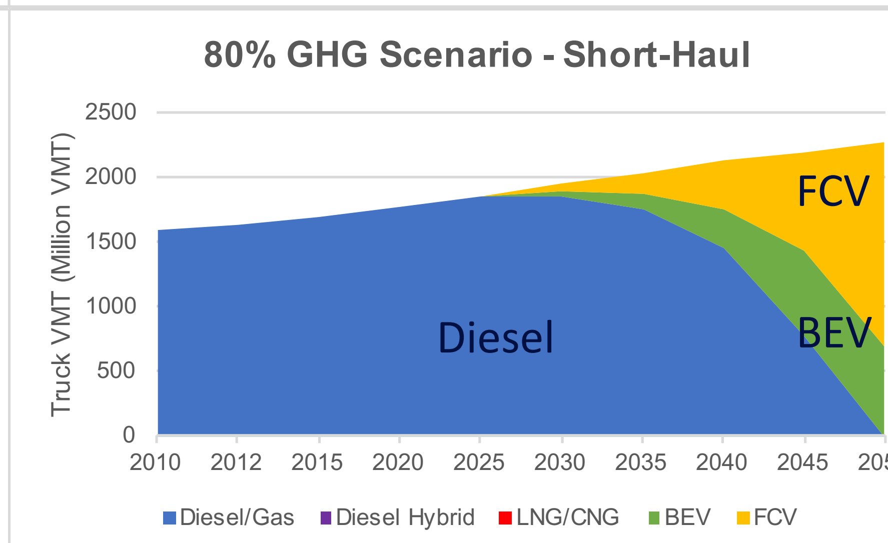
CA-TIMES Results

Scenarios: (L) BAU, (R) Carbon cap (80% reduction by 2050)



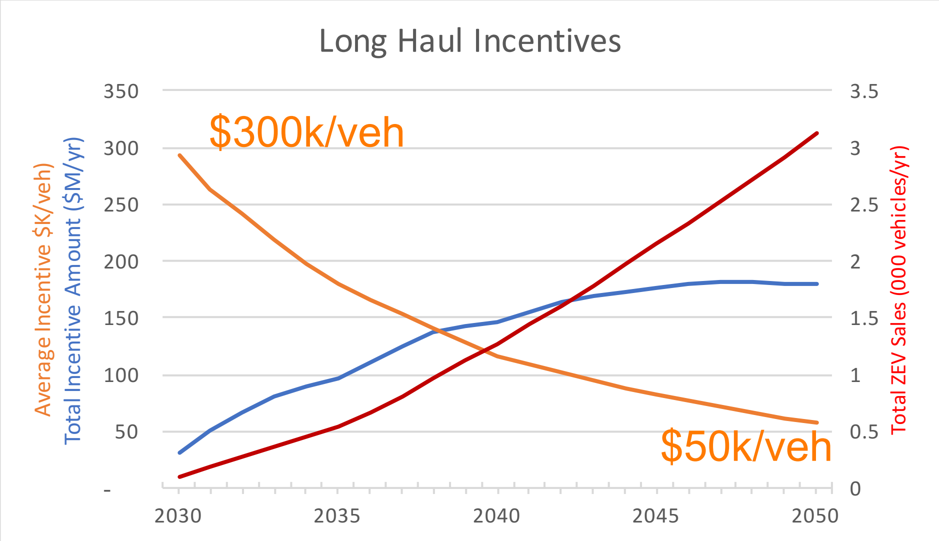


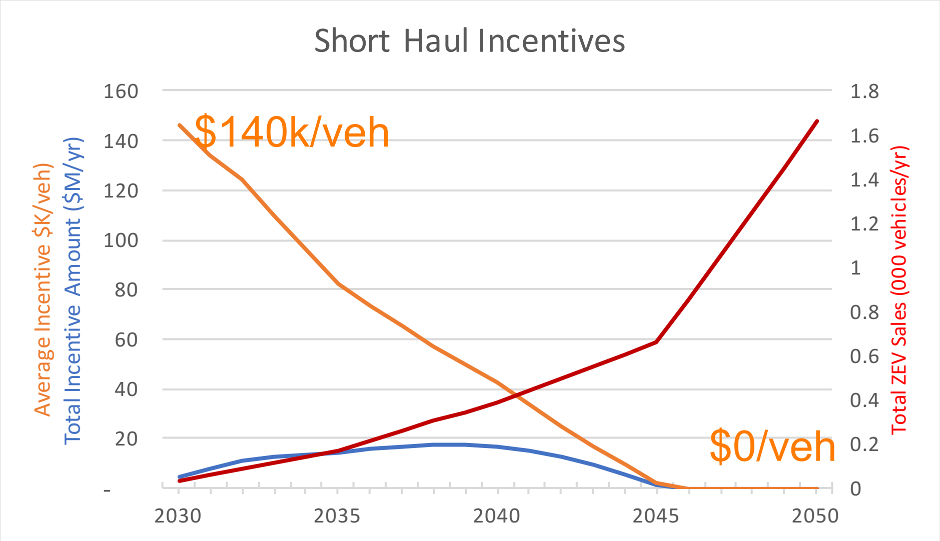




Truck Choice Analysis

- Identifying how to achieve a specific adoption target
  - Target of 25% ZEV adoption in each truck category by 2050
  - Carbon tax of $150/tonne CO_2 (~$1.90/Diesel Gal) in 2050.





  - **LH incentives**: cost total $2.8B for 29k extra ZEVs → $95k/veh
  - **SH incentives:** cost total $0.2B for 10k extra ZEVs → $18k/veh
  - Economic costs diff. (capital and fuel) vs BAU is $820 million for LH & SH
    - <$20,000 per vehicle (lifetime cost)
    - Difference of about $2.2 Billion used to overcome non-monetary utility factors

CA-TIMES Transportation Decarbonization

- CA-TIMES GHG reduction scenario is driven primarily by the goal of meeting carbon reduction goal of 80% by 2050
  - Requires decarbonization across supply and end-use sectors
  - Non-energy emissions are challenging to reduce
  - Transport > 90% reduction

Energy System Cost and Emissions (2010-2050)

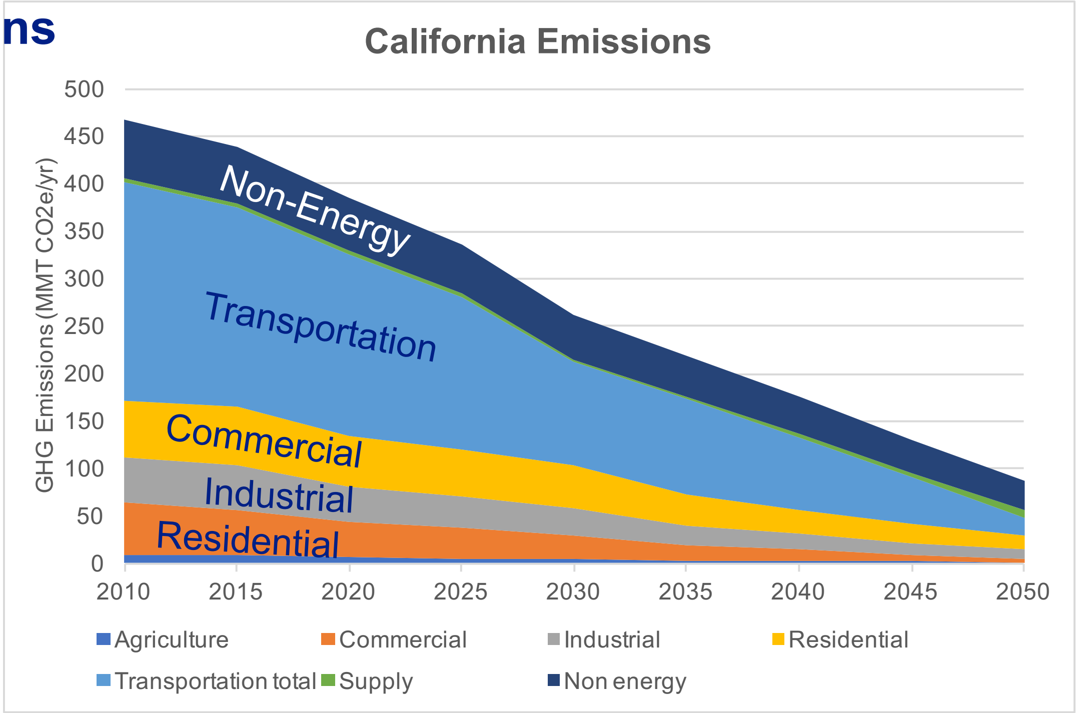
Cost ↑ vs BAU: $137B

Emissions ↓ vs BAU: 2804 MMT

$49/tonne CO_2e abatement

Relatively low average cost of emissions reduction

But this only includes economic costs and ignores other factors



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Discussion of modeling insights

- We have two models that have *very different* costs results:
  - Choice model - **Very high** levels of subsidies are required for carbon abatement, even though extra capital and fuel costs are **significantly lower**
  - Energy system model – **Modest** costs associated with carbon reductions across all sectors
- Carbon tax/price can have two meanings:
  - a calculation of the estimated extra economic costs associated with policies (may not include non-monetary factors)
  - as an policy instrument that can help to change behavior in the adoption of low-carbon technologies and fuels (should account for non-monetary factors)
- Highlights a tension in modeling between results that are societally optimal and behaviorally realistic

Conclusions and Takeaways

- In either BAU scenario, we don't see adoption of ZEVs and low-carbon technologies
- Choice Model Results
  - A ZEV mandate can achieve ZEV adoption but requires significant additional incentives (subsidies and carbon tax in our approach)
- CA-TIMES Results
  - Decarbonization of the energy system is a huge undertaking
    - Requires significant adoption of ZEVs in transportation
    - Fuel cell vehicles are chosen in the long-haul sector while FCVs and BEVs are chosen in short-haul
  - Cost of emissions reduction is relatively modest mainly due to cost savings from efficiency (highlighting the efficiency gap)

Conclusions and Takeaways (2)

- Adding behavioral elements to a model makes the results more relevant to the real-world
  - These real-world, behavioral elements are **barriers to adoption**
    - Capital and fuel costs
    - Refueling/charging inconvenience and costs
    - Model availability and risk/uncertainty
    - Technology readiness
  - The goal is to understand what is needed to drive adoption
    - Monetary incentives (subsidies, carbon tax)
    - Infrastructure deployment
    - Technology maturation and perception

Thank You

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