Medium- and Heavy-Duty Vehicle Choice Modeling and Applied Analysis (VAN 034)

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OVERVIEW

Timeline and Budget

FY 2020	FY 2021	FY 2022
$300,000	$300,000	$300,000

BARRIERS ADDRESSED

- Relating component-level technology R&D to national-level decarbonization and energy reduction benefits.
- Obtaining reliable and current medium- and heavy-duty (MDHD) market and operational data with sufficient detail/granularity.

PARTNERS

- NREL: Alicia Birky and Aaron Brooker, co-PIs; Lauren Sittler, Arthur Yip, Chen Zhang, Jason Lustbader, Fan Yang, and Evan Reznicek.
- DOE cross office: Vehicle Technologies Office (VTO), Hydrogen and Fuel Cell Technologies Office (HFTO), Bioenergy Technologies Office (BETO).
- 21st Century Truck Partnership (21CTP).

RELEVANCE

Objectives

- Provide critical tools and analysis to inform VTO research portfolio planning; explore energy-specific vehicle and transportation system advancements; and offer analytical insights on future research investments.
- Analyze transportation decarbonization scenarios to explore transition pathways to net zero emissions.

Relationship to Analysis Program Goals

- Market analysis of vehicle technologies using TRUCK and the MDHD Automotive Deployment Options Projection Tool (MDHD ADOPT) answers critical questions about the roles of technology progress and policy in future transportation decarbonization pathways.
- These modeling frameworks leverage core capabilities, including FASTSim and T3CO, developed for various activities across VTO and HFTO, and integrate multiple models to provide useful insights and metrics.
- The TRUCK payback methodology reflects adoption of cost-effective solutions and identifies opportunities for advanced vehicle technologies to reduce transportation and freight movement costs.

SUMMARY

- MDHD models and applied analysis provide critical information to inform VTO research as DOE sets goals to decarbonize the transportation system.
- NREL's approach maintains continuity of analysis support while developing enhanced and new capabilities, including both financial accounting and behavioral methodologies.
- Model enhancements have improved vehicle and market characterizations.
- Improvement and integration of existing tools provides a streamlined approach for both financially and behaviorally based approaches to market adoption and benefit assessment.
- Efforts are on track to meet FY 2022 milestones for decarbonization analysis.

APPROACH Dual path approach provides continuity of support while developing new capabilities.

TRUCK Workflow

The TRUCK Workflow integrates four models to provide an economically-based approach:

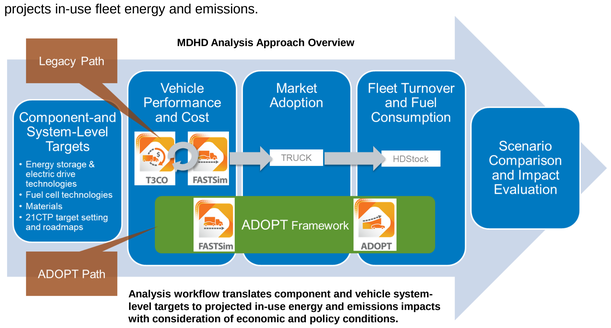
- FASTSim: Future Automotive Systems Technology Simulator estimates vehicle cost and fuel consumption,
- T3CO: Transportation Technology Total Cost of Ownership selects optimal vehicle attributes and efficiency improvements that minimize total cost,
- TRUCK: estimates market adoption based on financial considerations (payback), and
- HDStock: projects in-use fleet energy and emissions.

MDHD ADOPT Model

MDHD ADOPT fully integrates FASTSim and an internal stock model, leverages capabilities from light duty ADOPT, and provides a behaviorally-based approach.

- Includes consumer preferences for non-monetary vehicle attributes and benefits, such as acceleration.
- Iterative approach optimizes vehicle attributes and new vehicle offerings to maximize market share.
- Unit of analysis is individual make-models rather than a single composite vehicle for each powertrain type.

MDHD Analysis Approach Overview

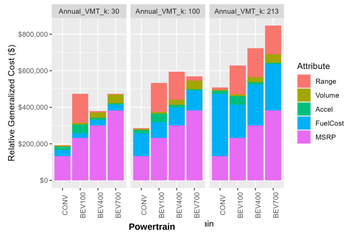


Analysis workflow translates component and vehicle system-level targets to projected in-use energy and emissions impacts with consideration of economic and policy conditions.

Modeling efforts in FY 2022 focus on:

- Improving vehicle models to more accurately represent vehicle characteristics and diversity;
- Improving model parameters and algorithms to more accurately represent vehicle operational requirements and market behavior;
- Integrating legacy tools in TRUCK workflow to enhance analysis realism;
- Enhancing T3CO to meet TDA needs; and
- Expanding MDHD ADOPT market coverage.

MDHD ADOPT Generalized Cost



MDHD ADOPT incorporates preferences for attributes beyond costs, with variation by annual VMT to reflect functional requirements such as daily range.

Decarbonization Pathway Analysis

Project goals in FY 2021 shifted from comparative benefits analysis to exploration of decarbonization pathways, considering technology progress alone and in combination with possible economic and policy futures.

FY 2022 Transportation Decarbonization Analysis (TDA) tasks:

- Perform analysis with both TRUCK and MDHD ADOPT using FY2021 input assumptions for two technology progress cases: "business as usual" and "technology success."
- Assess potential for decarbonization with technology progress alone.
- Investigate sensitivity to economic assumptions—principally fuel costs.
- Explore effectiveness and potential of policies, in isolation and in combination, to achieve decarbonization goals:
  - 70% zero emission vehicles (ZEVs) in MDHD truck sales by 2035, and
  - 100% by 2045.
- Update input assumptions regarding current status and future progress in technology performance and cost as needed per review by DOE technology managers.

Powertrain abbreviations:

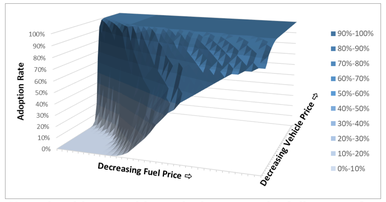
CONV: conventional diesel vehicle
FCEV: fuel cell electric vehicle
BEV: battery electric vehicle
HEV: hybrid electric vehicle.

ACCOMPLISHMENTS AND PROGRESS

TRUCK Workflow

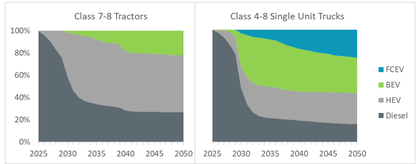
- Developed vehicle models for multiple tractor roof heights and straight truck weight classes and methodologies for aggregation of results to TRUCK market segments.
- Integrated T3CO into workflow to select attributes that minimize TCO within functional constraints for acceleration and gradeability, ensuring that vehicle evolution remains cost effective over time:
  - Implemented composite drive cycles,
  - Implemented technology cost curves,
  - Enabled multi-process runs in server environments, and
  - Developed post-processing scripts for integration with TRUCK.
- Developed new TRUCK algorithms to handle alternative powertrains with lower purchase price but higher fuel costs.

TRUCK Adoption Sensitivity



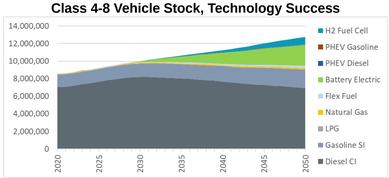
New algorithms enable analysis across the full range of vehicle and fuel price possibilities.

Class 4-8 Sales Shares, Technology Success Case



Technology advancement results in cost effective electrified solutions for 80% of the market in the analyzed segments, with ZEVs capturing 57% of single unit sales and 22% of tractors.

Class 4-8 Vehicle Stock, Technology Success

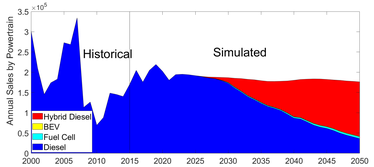


Diesel (includes hybrids) remains dominant in the commercial vehicle fleet without policy measures. Results are dependent on fuel and electricity price assumptions.

MDHD ADOPT

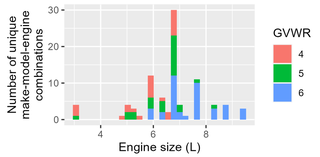
- Updated and improved model calibration.
- Improved simulation to ensure vehicles meet trace and provide accurate assessment of fuel consumption.
- Improved parameters controlling new model introductions.
- Added range preference dependence on usage bin based on VMT, specific to powertrain type, to enable differential treatment dependent on refueling / recharging speed.
- Processed class 4-6 data for expansion of model market coverage; calibration is on-going.
- Modified framework and parameters to add sensitivity to gross vehicle weight rating to accommodate expanded coverage of vehicle classes.

MDHD ADOPT Class 8 Tractor Sales, Tech. Success



MDHD ADOPT produces results similar to TRUCK for technology progress alone, with high adoption of hybrid diesels and low adoption of ZEVs in the Class 8 tractor market.

Class 4-6 Model Availability by Engine Size



Analysis of 2013 IHS Polk registration data by NREL used to initialize vehicle database and calibrate preferences.

Decarbonization Analysis Results

Initial analysis using FY 2021 input assumptions was completed with both the TRUCK and MDHD ADOPT paths.

- In the technology success case, hybridization is very cost effective in the tractor market and achieves a majority share by 2050, reducing energy consumption.
- BEVs see modest adoption in day cab tractors (regional haul) but very few ZEVs are adopted in sleeper tractors.
- ZEV powertrains are more cost effective in Class 4-8 single unit truck markets and capture more than 50% share of analyzed classes by 2050 (technology success scenario).
- Technology progress alone falls short of decarbonization goals when assuming the short payback requirements typical of these markets (2-4 years).
- Analysis assumes a relatively high electricity price to account for amortization of infrastructure costs.
- Sensitivity to fuel and electricity price and vehicle incentives to be explored in the remainder of FY 2022.

FASTSim T3CO ADOPT

FUTURE WORK/ CHALLENGES AND BARRIERS

Remainder of FY 2022

- Collect remaining FY 2022 input updates from VTO and HFTO technology managers.
- Update scenario analysis and explore tipping points with sensitivity to:
  - AEO 2022 fuel price cases and range of electricity prices from published studies;
  - Range penalty & charging availability; and
  - Vehicle purchase incentives.
- Provide inputs on energy demand to BETO and HFTO modeling efforts.
- Q4 Milestones:
  - Paper on modeling capabilities, and
  - TDA results for final DOE review.

Potential FY 2023 Work

- Develop methodologies to assess the impact of local criteria emissions on urban and disadvantaged communities.
- Address market diversity in TRUCK workflow through model development that enables vehicle optimization for market share within each segment.
- Complete MDHD ADOPT development to encompass full commercial vehicle market.
- Leverage new data sources, including the upcoming VIUS release, to update and improve models.

Any proposed future work is subject to change based on funding levels

COLLABORATION AND COORDINATION

Coordination across DOE to establish appropriate modeling inputs:

- VTO program managers with MDHD portfolio activities, including SuperTruck, Materials, Advanced Engine and Fuel Technologies, Electric Drive Technologies, and Energy Storage;
- HFTO - MDHD vehicle targets and analysis; and
- BETO.

Leveraging NREL team efforts across VTO, HFTO, BETO, EERE Strategic Analysis, and work for others where possible:

- Expertise, knowledge, model development, data, and analytical insights; and
- Outcomes from 1 MW+ charging and depot charging projects.

Collaboration with industry through 21st Century Truck Partnership:

- NREL TDA team member participation in tech team and working group meetings and active support of analyses.
- NREL leadership of the Electrification Infrastructure and Freight Operational Efficiency working groups.
- Presentation of assumptions, methodology, and results for review and feedback.

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VMT = vehicle miles traveled; GVWR = gross vehicle weight rating
VIUS = Vehicle Inventory and Use Survey

DOE Vehicle Technologies Office
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Washington, D.C.
June 21–23, 2022
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