Light-Duty Vehicle Choice Modeling and Transportation Decarbonization Analysis

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National Renewable Energy Laboratory (NREL)
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DOE Vehicle Technologies Program
2022 Annual Merit Review and Peer Evaluation Meeting

Project ID # van018

Overview

Timeline

- Project start date: 10/01/2019
- Project end date: 09/30/2022
- Percent complete: 80%

Budget

- Total 3-year funding: $900K
  - DOE share: 100%
- Funding for FY 2021: $300K
- Funding for FY 2022: $300K

Barriers Addressed

- Assesses cost and technology barriers to decarbonization being addressed by VTO R&D
  - Adv. Engine & Fuel Tech
  - Electrification Technologies
  - Batteries
  - Material Technologies
  - Fuel Cells
  - Hydrogen Storage

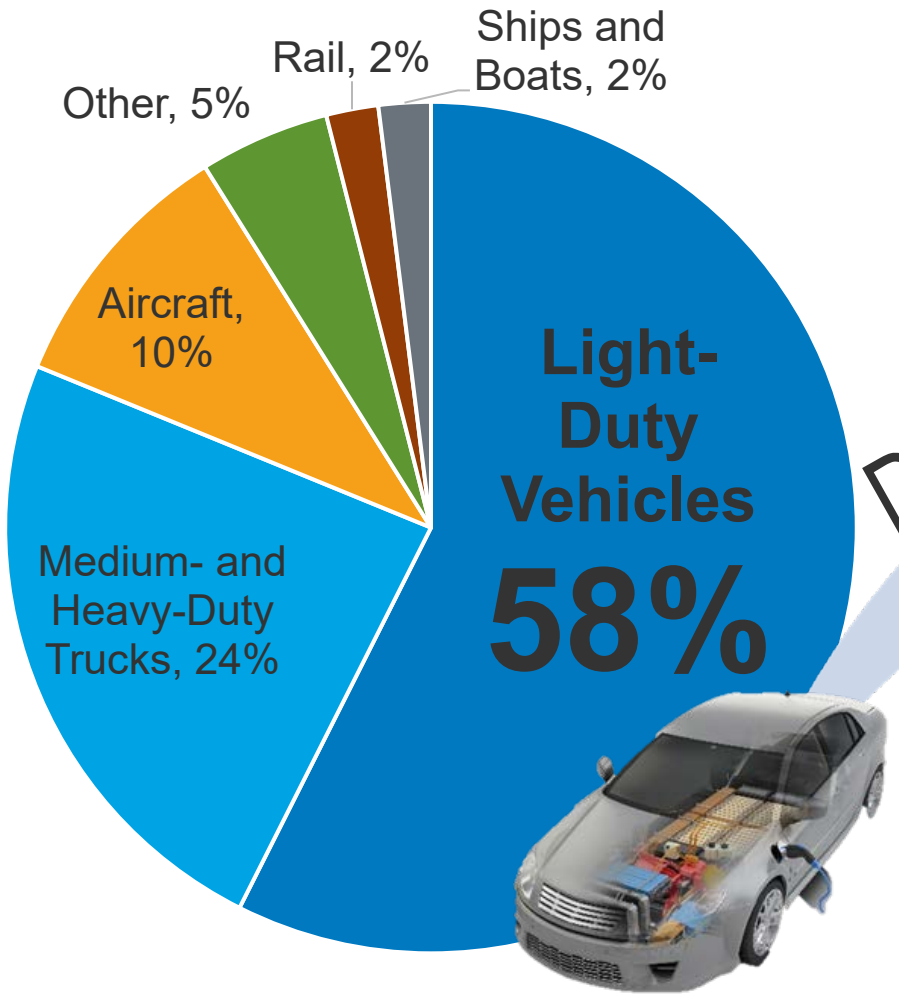
Partners and Collaboration

- Project lead: NREL
- Analysis leads in VTO, HFTO and BETO, plus technology managers for batteries, electrification, fuel cells and hydrogen storage, materials, and combustion

R&D = research and development; VTO = Vehicle Technologies Office
HFTO = Hydrogen and Fuel Cells Technologies Office; BETO = Bioenergy Technologies Office

Relevance: Find decarbonization pathways

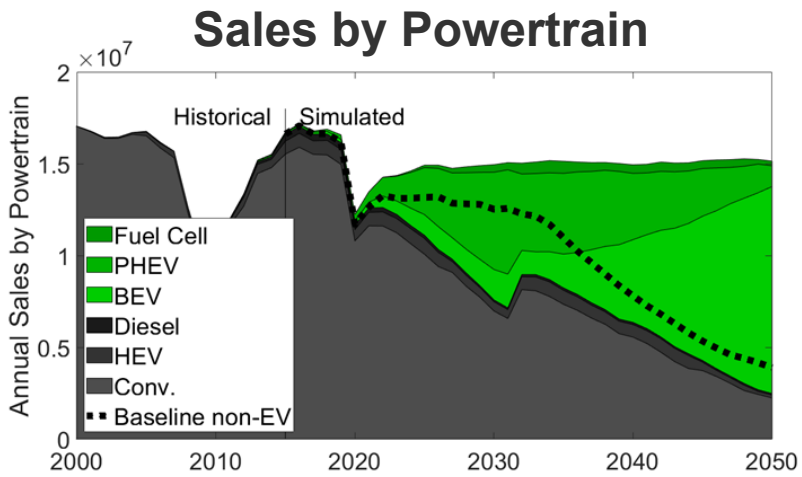
U.S. Transportation Carbon Emissions

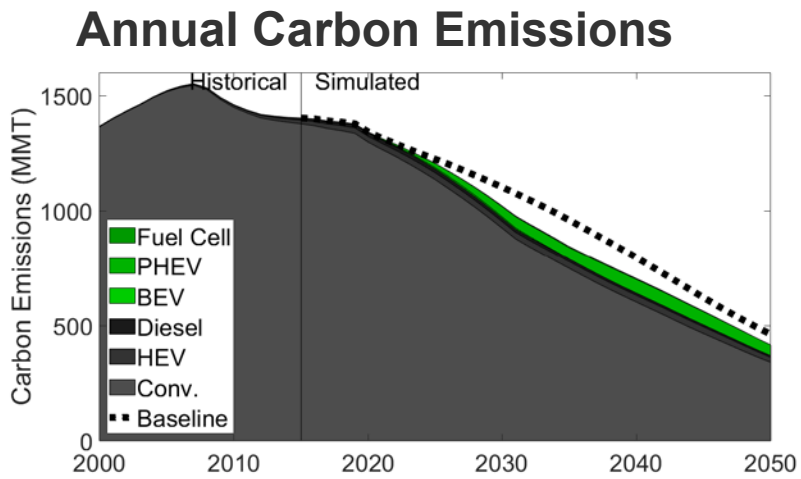


Decarbonization

R&D

- Batteries
- Motors
- Power electronics
- Materials
- Fuel cells
- Hydrogen storage





https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

PHEV: Plug-in hybrid electric vehicle, BEV: Battery electric vehicle, HEV: hybrid electric vehicle, Conv.: Conventional gasoline vehicle

FY2022 Milestones

- ✓ Q1: Demonstrate agreed-upon procedure for translating Transportation Decarbonization Analysis (TDA) scenario outputs to the aggregation level needed by the Annual Technology Baseline (ATB) for composite vehicle attributes

- ✓ Q2:
  - ✓ Initiate input elicitation under the 2022 TDA work scope
  - ✓ Model documentation updates

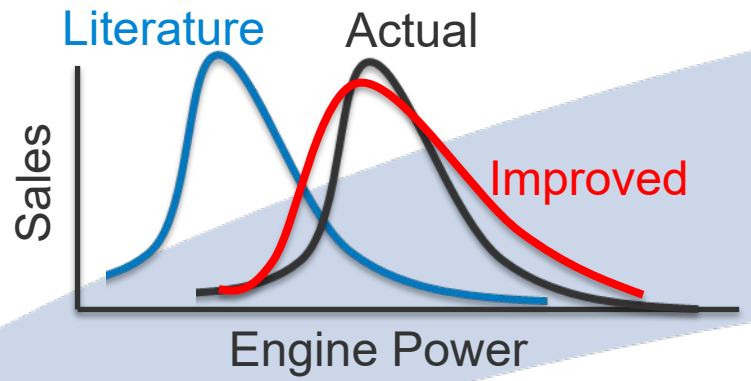
- Q3: Ongoing/on track
  - Status report on TDA activities

- Q4: Ongoing/on track
  - Final TDA reporting—highlighting how far different combinations of technology progress and market/policy conditions get toward achieving TDA goals

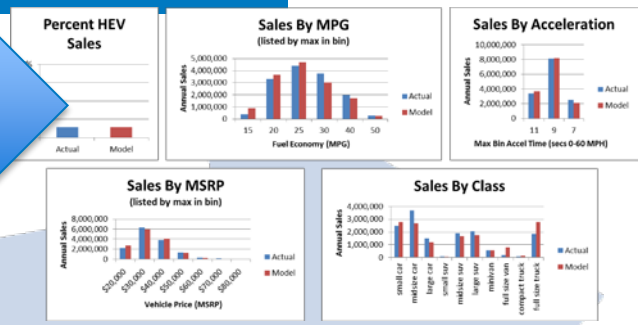
Approach Background and Collaboration

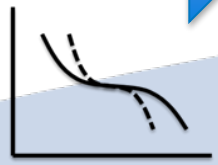
- Choice modeling did not match actual data well
- We started improving by recalibrating

Choice Modeling (20 years ago)



Matched even better





Additional preference improvements

- Nonlinear
- Income dependent

ADOPT

Correctly found that equivalently performing HEVs did not sell well

~20 years ago, compared cost of powertrains with equivalent performance

Big picture, the approach was wrong:

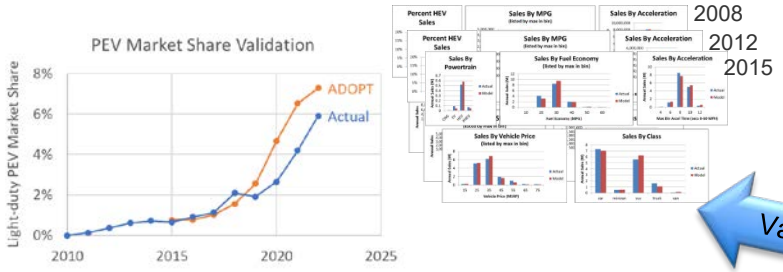
- One HEV did sell well – top 10 for cars
- It did not have equivalent acceleration – bottom 10
- It traded-off performance for MPG and cost
- Another HEV also traded-off size, but did not sell well
- Requires a choice model to capture trade-offs
- Also needed for Battery Electric Vehicles (BEVs): With equivalent range, BEVs cost more though are faster

Collaboration through meetings and discussions

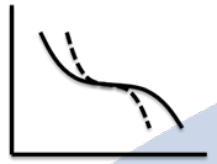
- VTO
- ORNL
- ANL
- LBL
- EIA
- OEMs

Approach: Evaluate Decarbonization with ADOPT

ADOPT

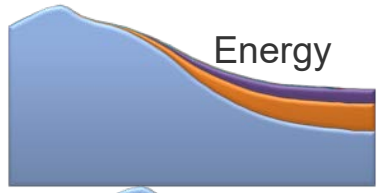


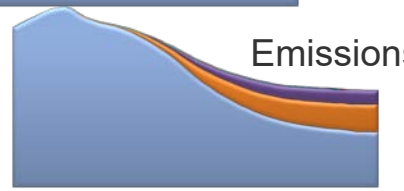
Validation



Consumer Preferences
- Nonlinear
- Income dependent

Regulations
- CAFE
- GHG Rule
- Incentives





Transportation Decarbonization

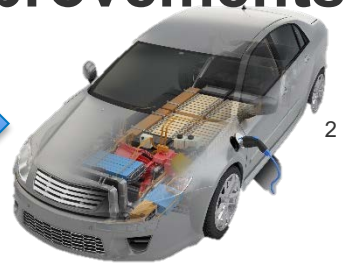
Market Driven Future Options

All Existing [1] Makes/Models

FASTSim

Technology Improvements

Goals from DOE Technology Managers



[2]

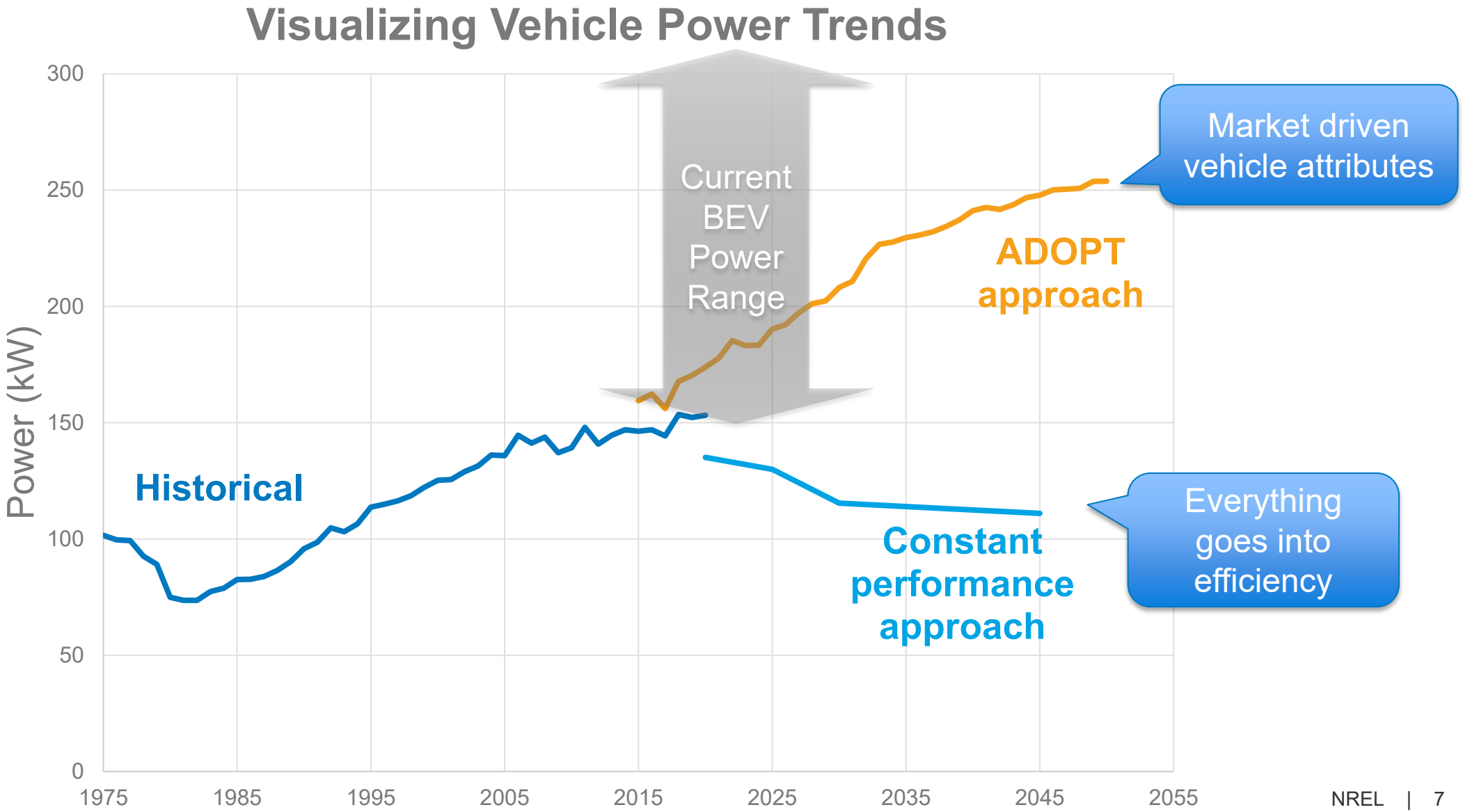
Images credits
1. D. Schroeder, NREL
2. Josh Bauer, NREL

FASTSim: Future Automotive Systems Technology Simulator

PEV: Plug-in electric vehicle
CAFE: Corporate Average Fuel Economy
GHG: Greenhouse Gas Emissions

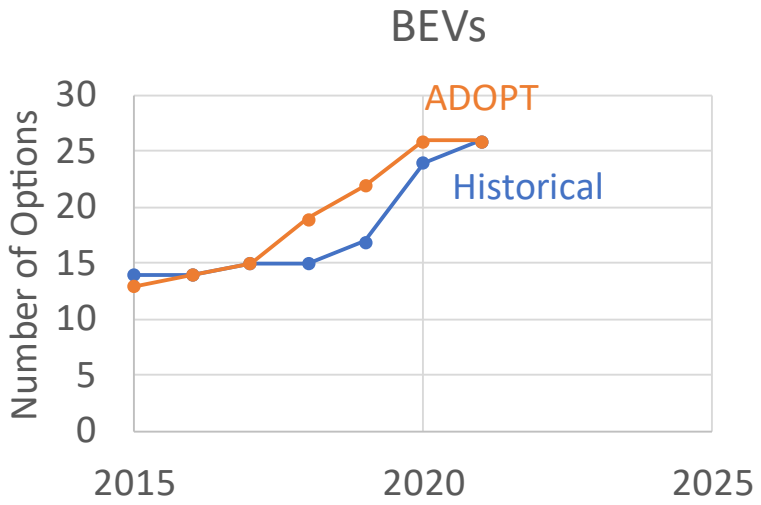
Approach: ADOPT Matches Historical Trends

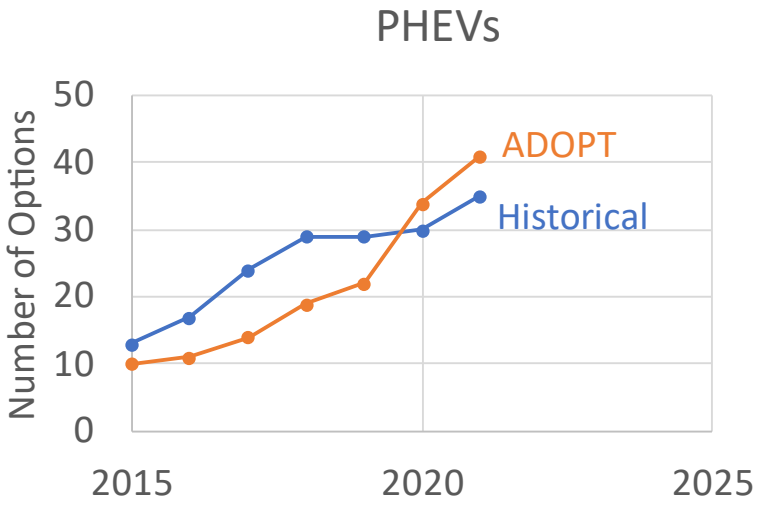
Recent Fact of the Week highlighted average power reaching all time high for model year 2021 LDVs



Technical Accomplishments: Improved Approach

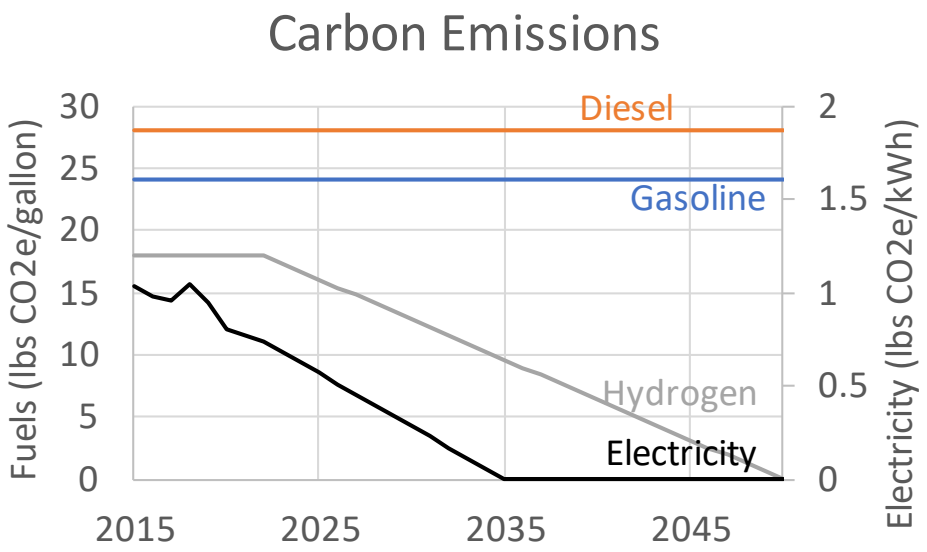
- Create new options for best-selling, now by income bin
  - If BEVs are selling best for high-income households, creates more BEVs for high-income households
  - Matches trend of more high-priced BEV options
- Improved new option creation model to match historical PEV trends
- Updated CAFE/GHG regulations
- Added capability to model new incentives being discussed
  - Up to $12,500
    - $4,000 base + $4,500 domestic assembly + $500 domestic content
    - $3,500 if battery energy is more than
      - 40 kWh before 2027
      - 50 kWh after 2026
  - Includes vehicle price thresholds
    - $55,000 for cars
    - $64,000 for vans
    - $69,000 for SUVs
    - $74,000 for Pickups
  - Captures instant rebate vs. tax credit effectiveness
    - Tax credits are assumed to be valued at 55% of the rebate amount due to the delay and risk of qualifying

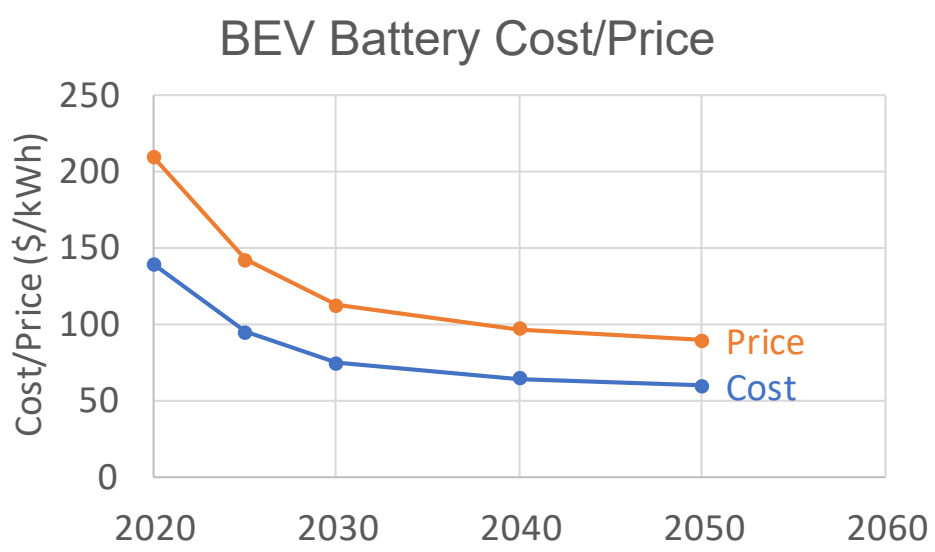


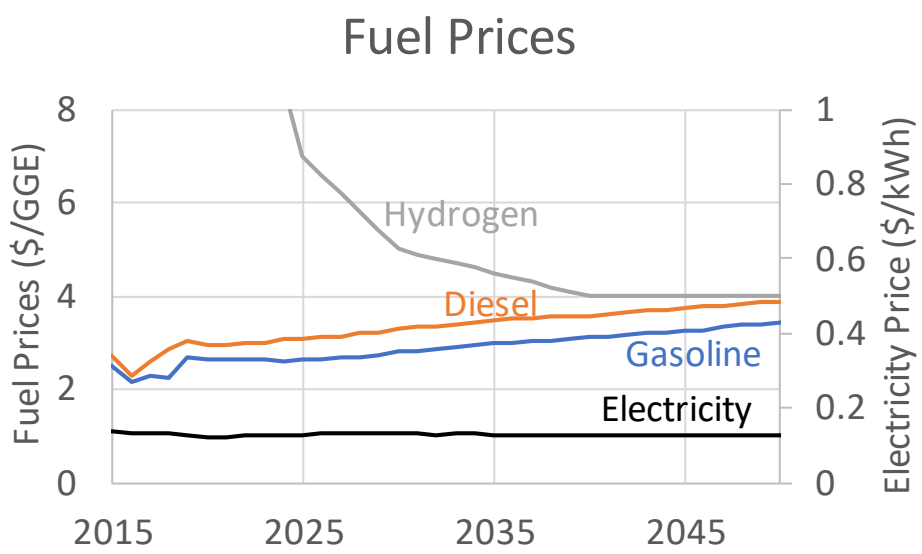


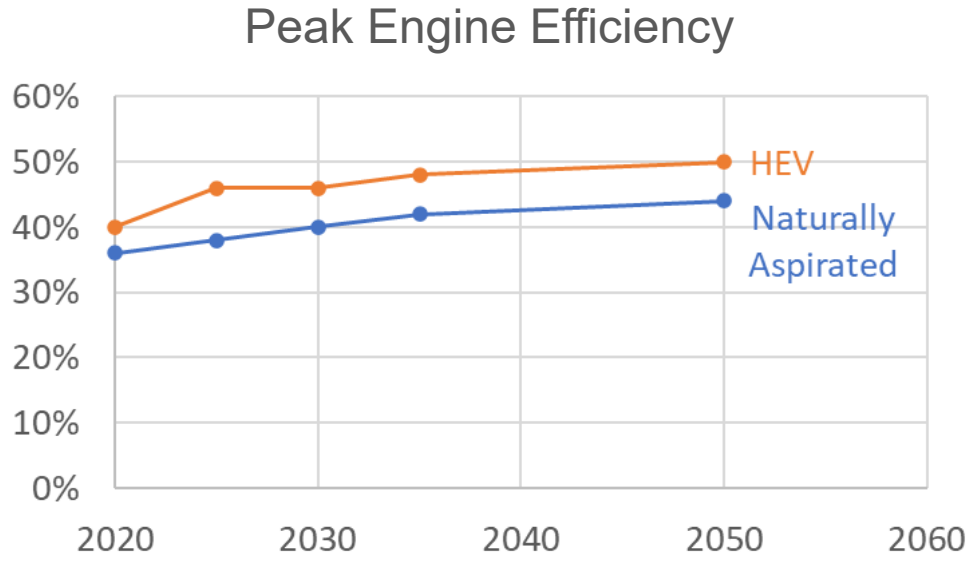
https://www.congress.gov/bill/117th-congress/house-bill/5376/text Sec. 36C. New Qualified Plug-in Electric Drive Motor Vehicles

Technical Accomplishment: Updated Key Assumptions









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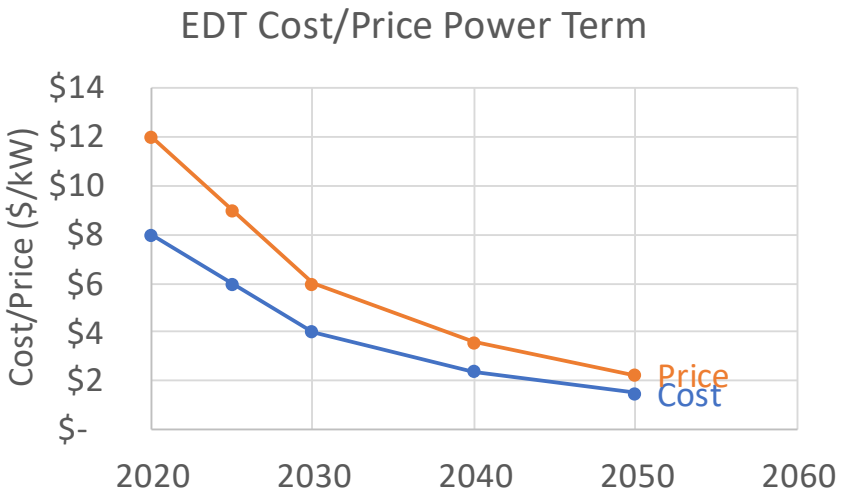
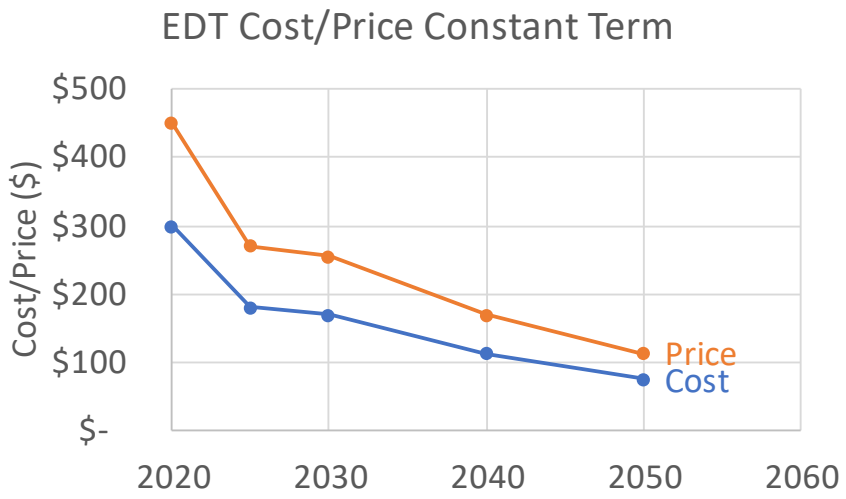
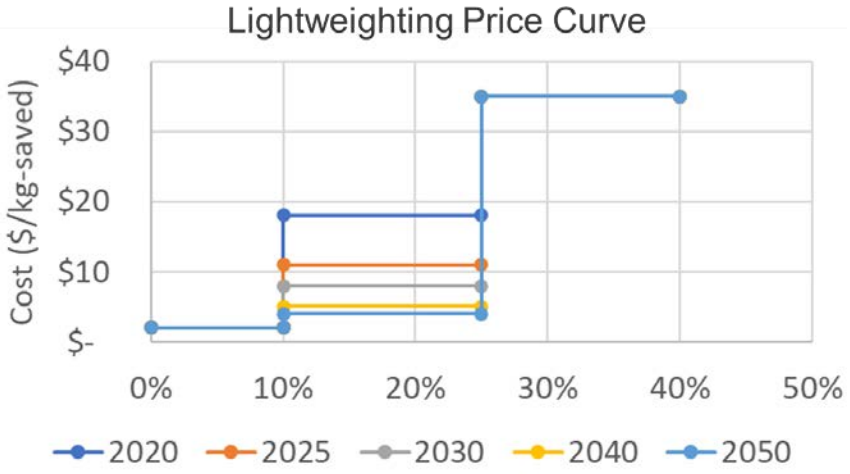
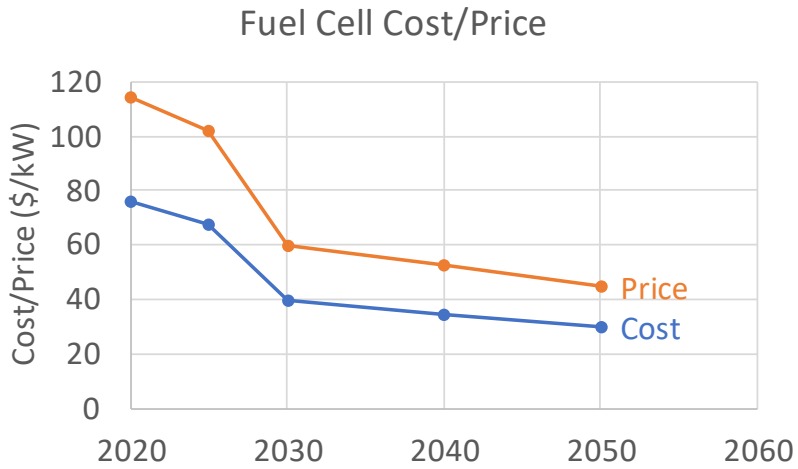
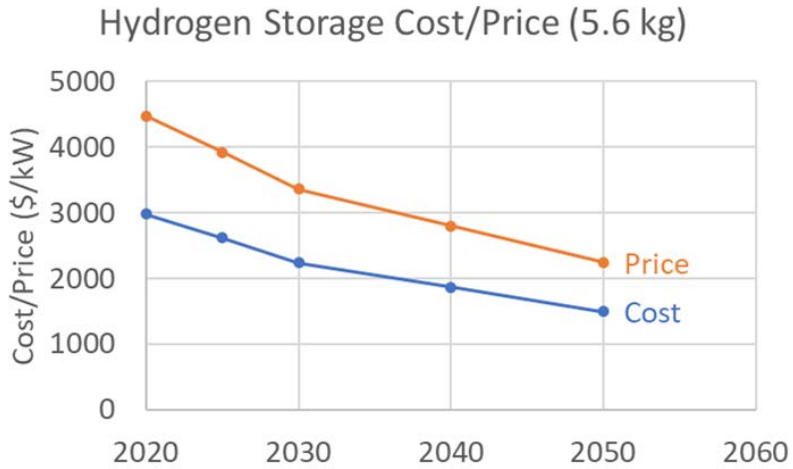






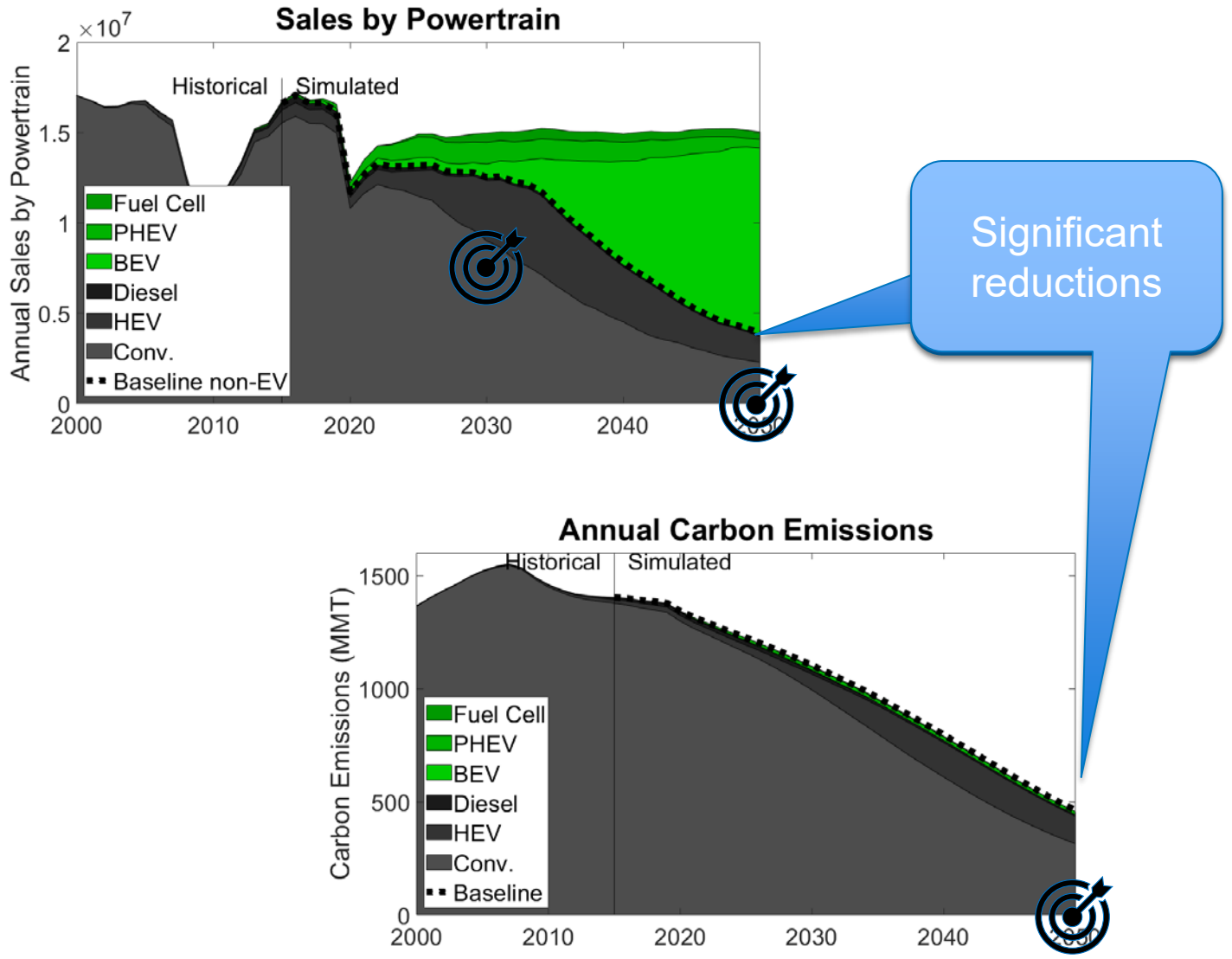




Technical Accomplishments: Evaluated Decarbonization Potential Based on Technology Success with Previous Policies

Scenario assumptions:

- Technology success
- SAFE CAFE/GHG
- $7,500 tax credit for 200k PEVs/manufacturer

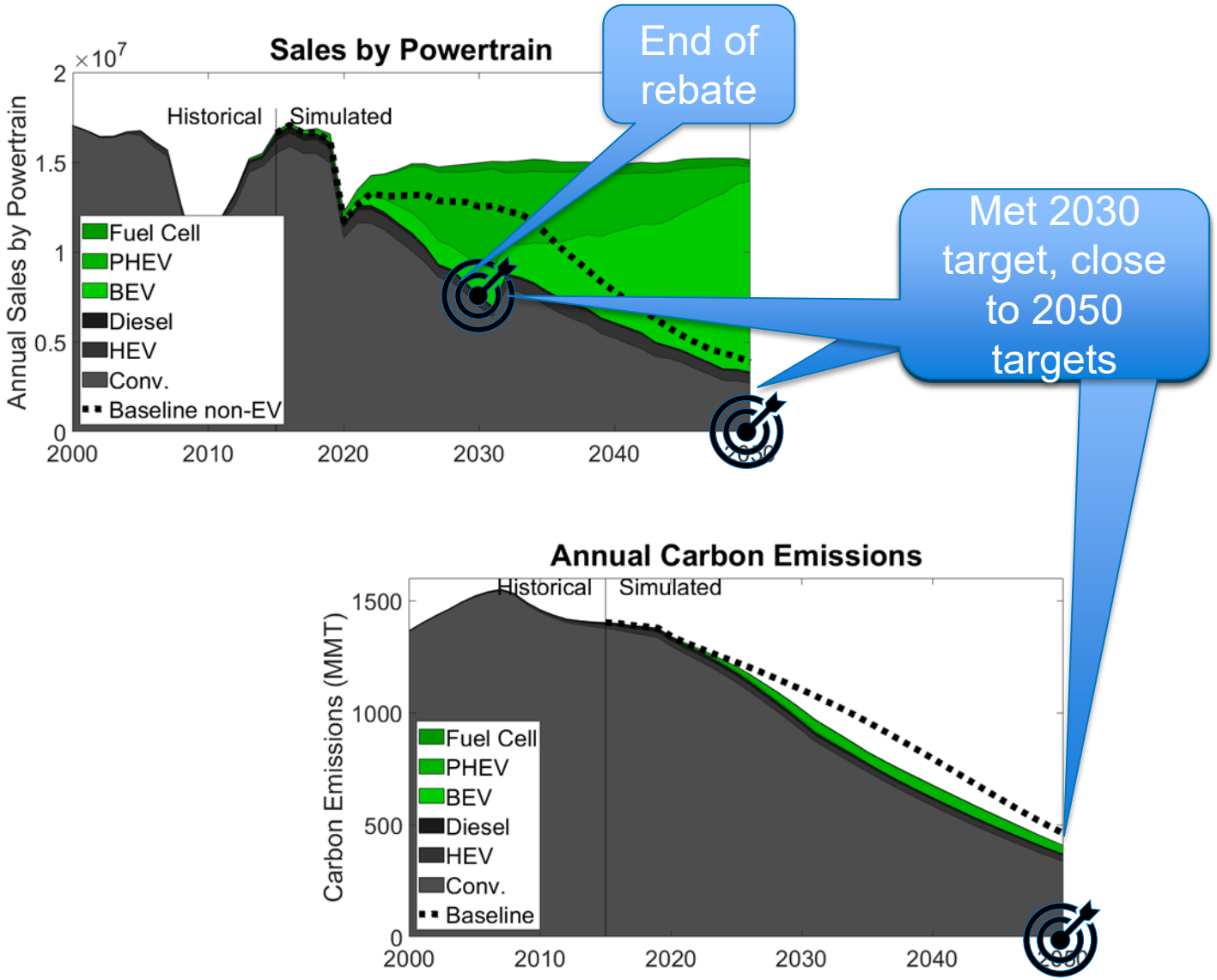


SAFE: Safer Affordable Fuel-Efficient Vehicle Rule

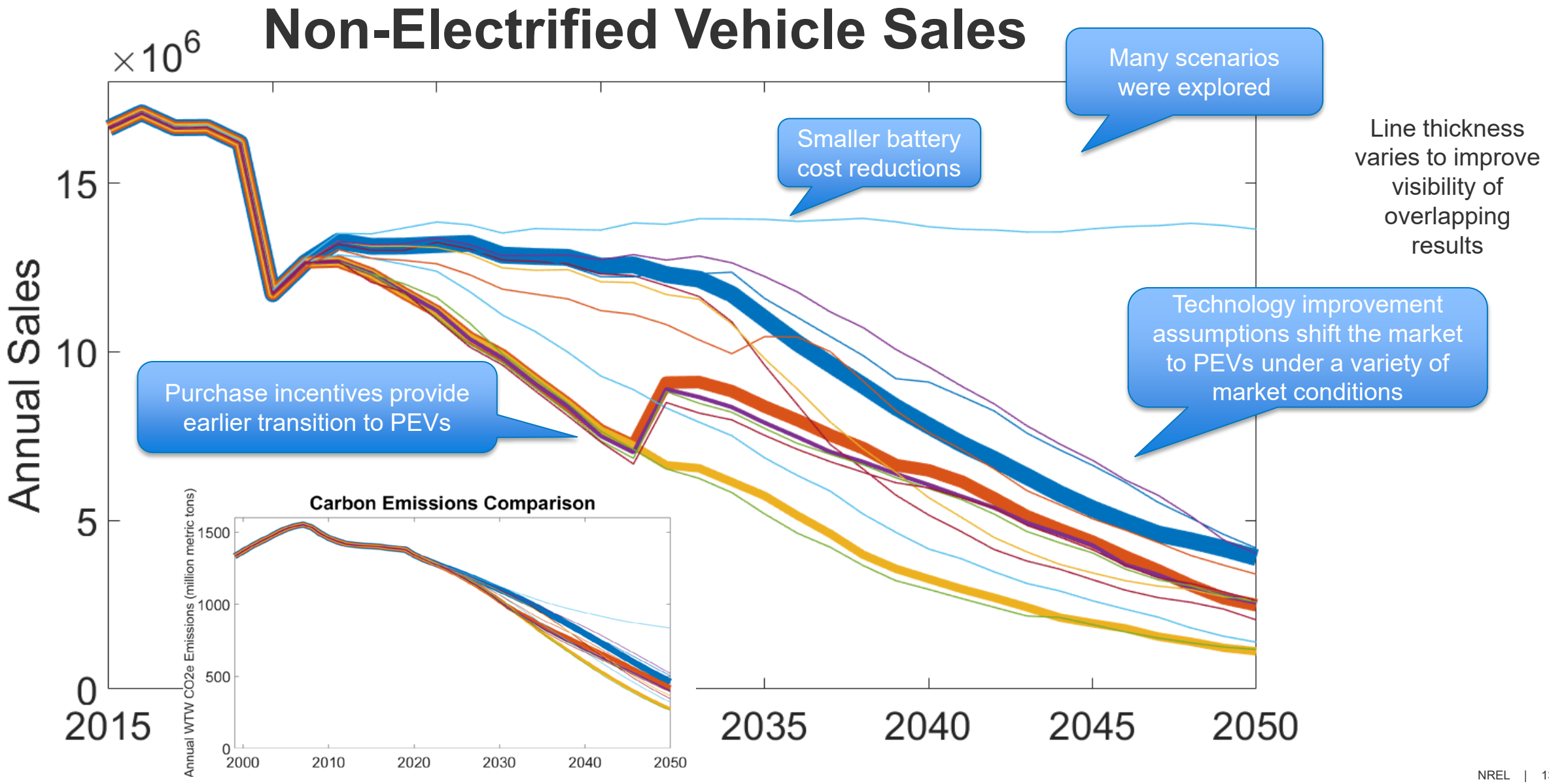
Technical Accomplishments: Evaluated Potential from Technology Success with Proposed CAFE/GHG & Incentives

Scenario assumptions:

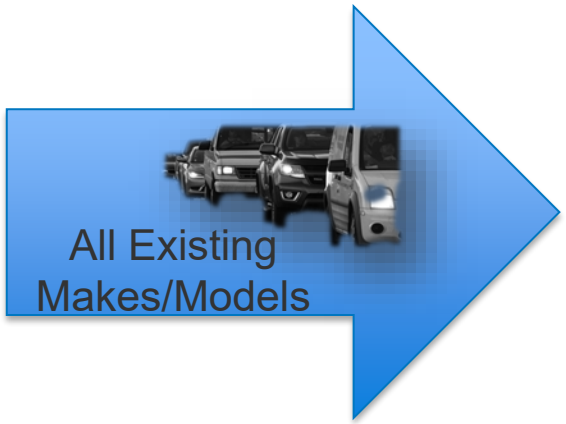
- Technology success
- 8% CAFE/GHG increase 2024-2025, 10% in 2026
- $12,500 instant until 2031

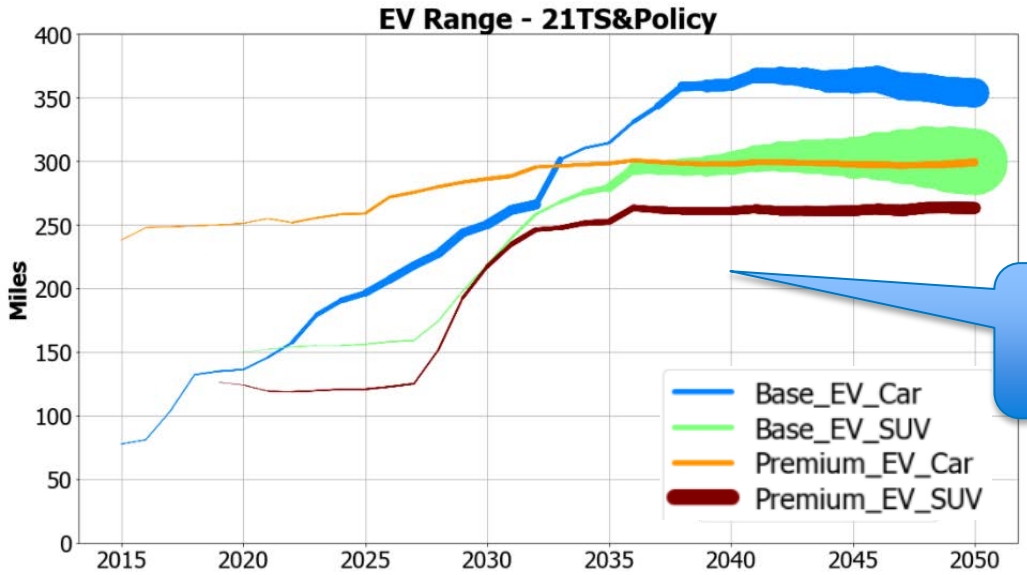


Technical Accomplishments: Evaluated Many Other Pathways to Decarbonization



Technical Accomplishment: Aggregated TDA Vehicles into Composite Vehicle Attributes for Applications like ATB

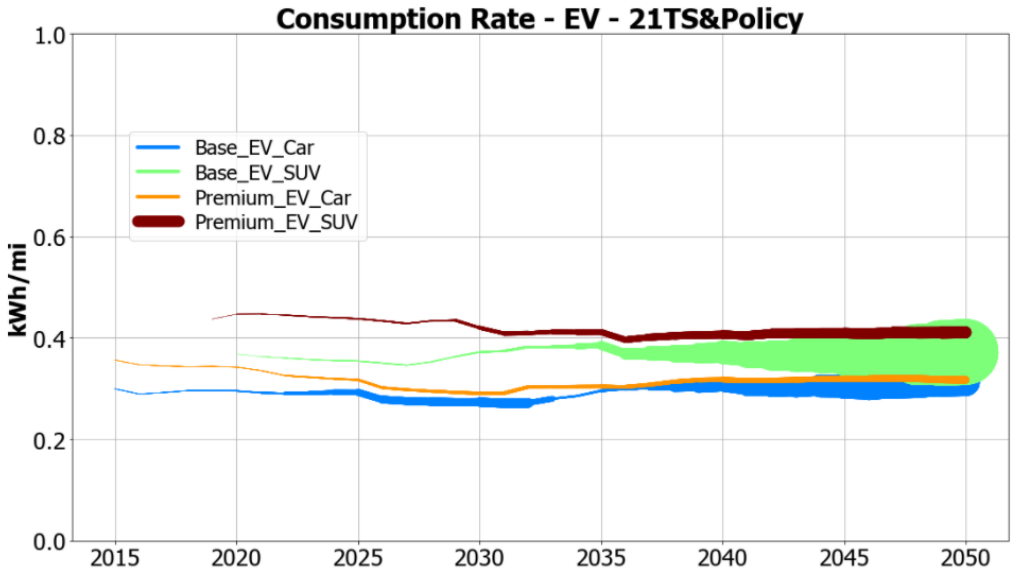


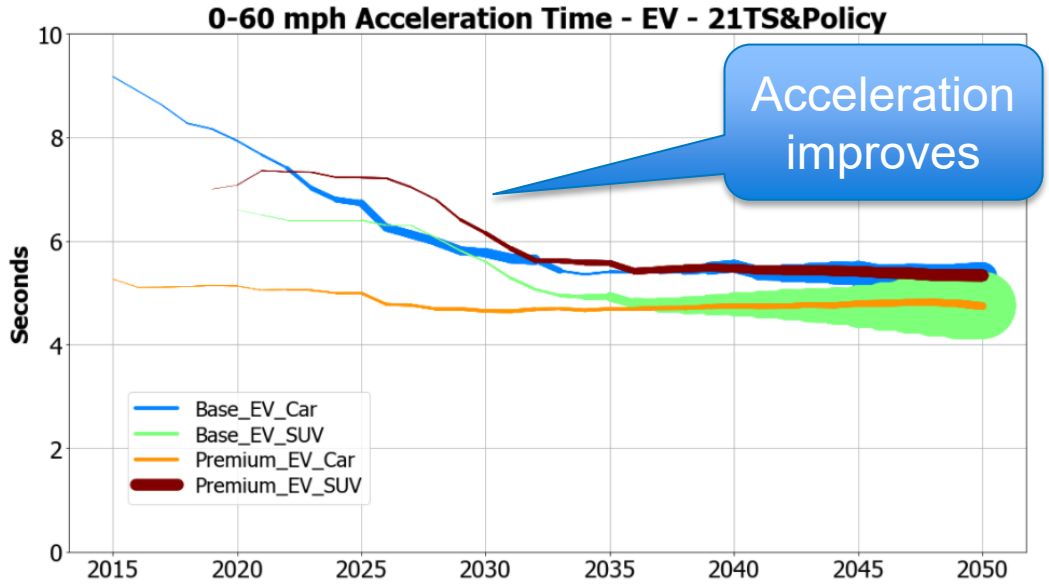


Completed for all powertrains

EV range increases

Line thicknesses indicate relative sales shares





Acceleration improves

ATB: Annual Technology Baseline

Response to Previous-Year Reviewer's Comments

- 9 out of 10 reviewers provided positive feedback on all topics
  - All the detailed reviews and recognition of the team's efforts are greatly appreciated
  - The feedback is helpful to reinforce what we are doing right and how to continue improving
- One reviewer disagreed with the others, especially on the approach
  - *"It is difficult for this modeling exercise to keep up with the fast-changing pace in vehicle technologies and consumer preference. It is not clear what the value proposition is."*
  - ADOPT is fully integrated to be able to address fast-paced changes
    - Just requires entering inputs on prospective technology progress, energy costs and policy conditions to output scenario results (vehicles are created and updated endogenously)
      - We regularly update all technology progress scenarios anticipated by tech managers and industry
    - Regularly keep up with evolving policy considerations, e.g.:
      - Updated CAFE/GHG standards to SAFE and then to 8%/yr. improvement for 2024-2025, 10% in 2026
      - Updated to proposed purchase price incentives, including battery size and vehicle price/type limits
    - Capable of providing results in response to quick turnaround requests
  - Unique among comparable models, ADOPT matches historical sales over many dimensions and years without changing the consumer preference settings (or any calibration factors), suggesting preferences for key attributes are predictive rather than "fast changing"
    - While other models require yearly varying alternative specific constants to match ground truth sales data (implying key preferences are changing or cannot be represented), ADOPT's robust multi-year validation suggests otherwise

Collaboration and Coordination

- Coordinate with VTO, HFTO and BETO Analysis leads, plus MDHD efforts under VAN034 for holistic cross-sector decarbonization analysis
- Met with technology managers in each area to update R&D goals
  - Batteries
  - Electrification technologies
  - Fuel cells and hydrogen storage
  - Materials and lightweighting
  - Advanced Engine and Fuel Technologies
- Collaborated extensively with Materials technology managers and industry tech team to establish goals for reducing carbon emissions
- All other tech managers also interface with industry for input on targets

MDHD = medium- and heavy-duty vehicles

Remaining Challenges and Barriers

- Improve analysis for diversity, equity, and inclusion (DEI)
  - Vehicle electrification has primarily benefitted high-income households via accompanying:
    - Purchase incentives
    - Low fuel cost
    - Lower pollution
    - Lower maintenance
  - Need to find ways to improve DEI

- Continue to improve modeling approach for DEI
  - Currently capture sales by household income
  - Need to expand

Proposed Future Research

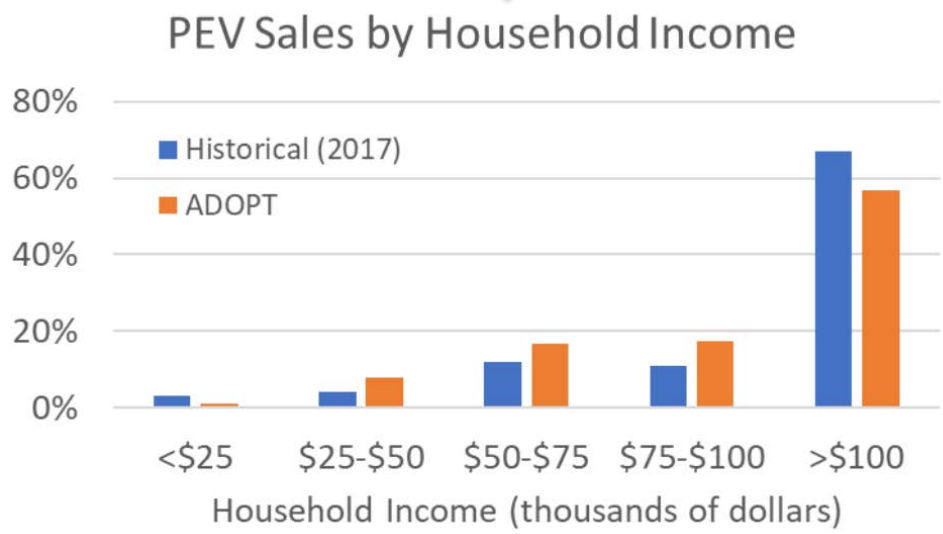
FY 2022 (ongoing)

- Complete collection of latest input updates from technology managers
- Complete ADOPT updates, including:
  - Latest AEO input assumptions and fuel price sensitivities
  - Latest changes to CAFE/GHG standards, and other considered policies
  - Breakout of electric vehicle sales by income to begin addressing equity
- Q4 Milestone:
  - Final Transportation Decarbonization Analysis reporting for DOE review

Potential FY 2023

- Explore more scenarios relating to equity
  - PEV sales by household income level
  - Pathways to more equitable PEV sales (purchase incentive price limits, income limits)
  - Multivehicle household impact on BEV purchases
- Update input assumptions as needed
  - Fuel prices and emissions factors
  - Latest tech progress scenario assumptions
- Complete additional ADOPT updates to improve accuracy and value
  - Based on feedback from tech managers and this review

ADOPT matches well historically for confidence in exploring more equitable pathways in the future



AEO = Annual Energy Outlook

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

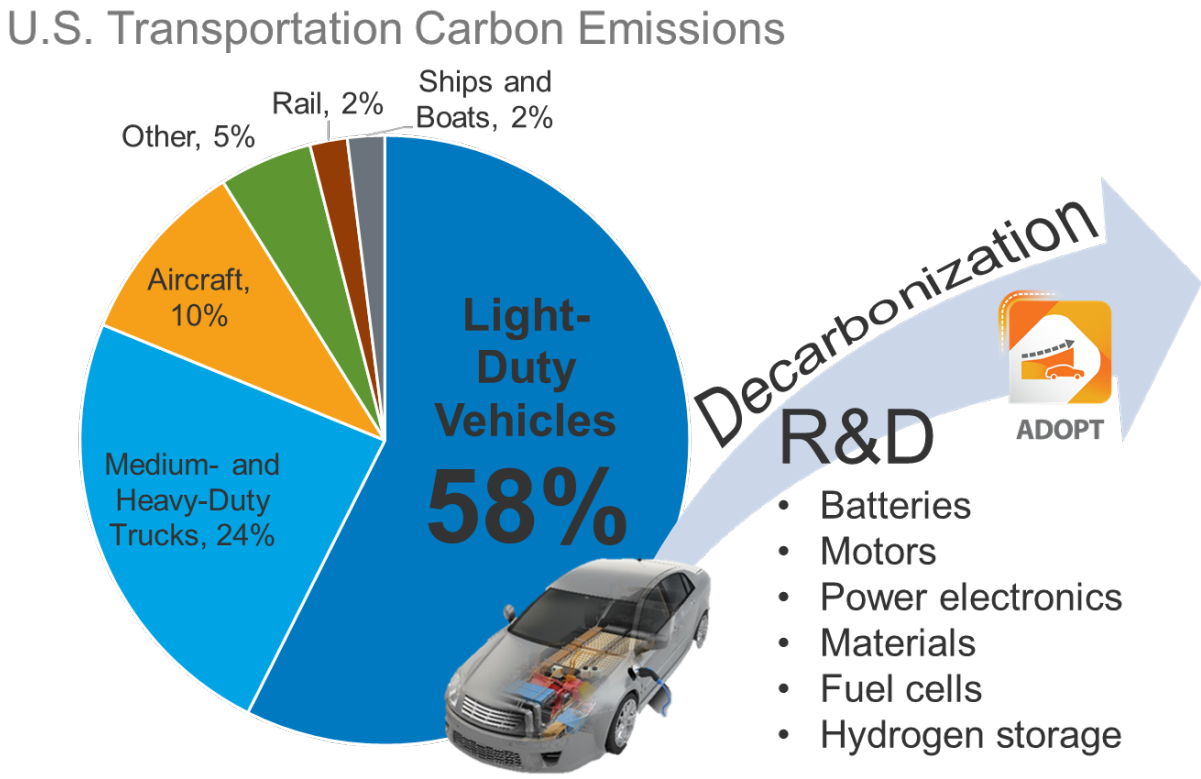
Summary

- Light-duty vehicles are responsible for most transportation carbon emissions

- This effort finds & explores decarbonization pathways
  - Impact of R&D
  - Sensitivity to market conditions
    - Regulations
    - Incentives
  - Low-cost pathways
  - Fast turnover pathways

- Uses ADOPT for confidence in the results
  - Choice model needed to capture trade-offs
  - Validates with historical sales
  - Endogenous new model option creation

- Next steps
  - Continue to improve ADOPT, especially for equity
  - Add analysis focused on equity



Thank You

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Technical Back-Up Slides

Approach: ADOPT

Structured and efficient approach

- A user interface provides
  - Easy input and vetting (charts) of technical targets and assumptions
  - Data management of scenarios
  - Extensive review of results
- Endogenously creates future vehicle options unique to each scenario
  - Optimizes vehicle component sizes (engine power, battery energy, etc.) to achieve best combination of consumer preferences
  - Each optimization runs the FASTSim vehicle powertrain model through U.S. Environmental Protection Agency (EPA) fuel economy tests and acceleration tests (hundreds of thousands of drive-cycle simulations)
- Runs each scenario in 1–4 hours overnight.