Light-Duty Vehicle Choice Modeling and Benefits Analysis

Aaron Brooker (PI and Presenter)
Jeff Gonder, Dong-Yeon Lee, Lijuan Wang
National Renewable Energy Laboratory (NREL)
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DOE Vehicle Technologies Program
2020 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: 20%

Budget

- Total project funding: $900K (pending future appropriations)
  - DOE share: 100%
- Funding for FY 2019: N/A
  - Though this project builds upon previous activities
- Funding for FY 2020: $300K

Barriers

- Rigorous modeling and applied analysis needed to assess program benefits and inform portfolio planning related to:
  - Advanced Combustion
  - Electrification Technologies
  - Batteries
  - Material Technologies
  - Fuel Cells
  - Hydrogen Storage

Partners

- Project lead: NREL
- Argonne National Laboratory
- DOE technology managers

Relevance

Objective: Estimate the energy and emission benefits of vehicle technology research

- Vehicle electrification, including batteries, motors and power electronics
- Combustion and materials
- Fuel cells and hydrogen storage

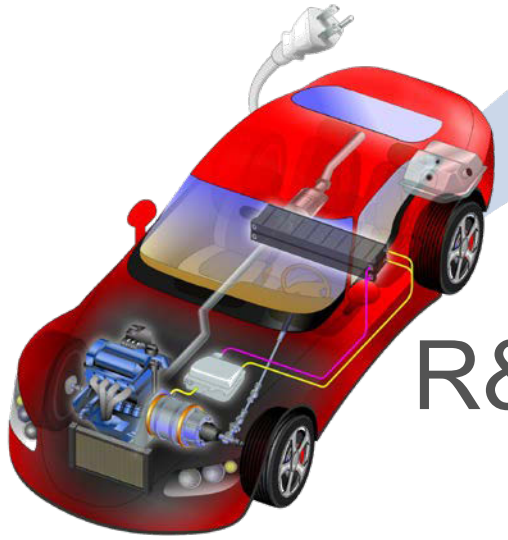
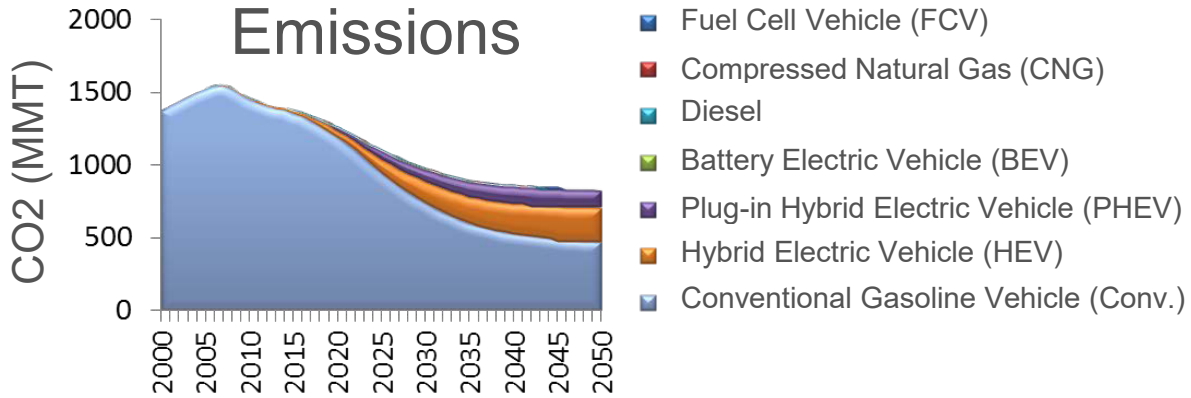
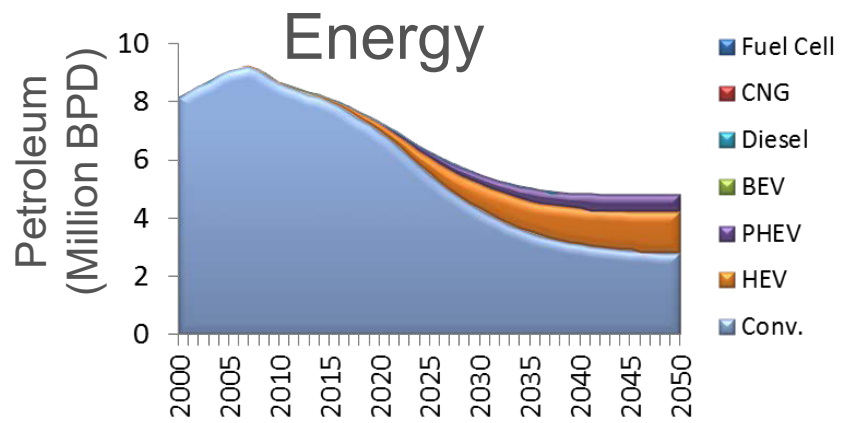


Image by Jim Snyder, NREL

R&D

Benefits





BPD: barrels per day
MMT: million metric tons
R&D: research and development

FY2020 Milestones

- ✓ Q1: Update DOE on Light Duty Automotive Deployment Options Projection Tool (ADOPT) enhancements.

- ✓ Q2: Share preliminary light-duty (LD) benefits analysis runs with DOE for review and feedback.

- Q4: Ongoing
  - Deliver completed LD Benefits Analysis Report for final DOE review.
  - Go/No-Go: Confirm success of streamlined process and assess priorities for FY21, including refining/updating input assumptions and model features.

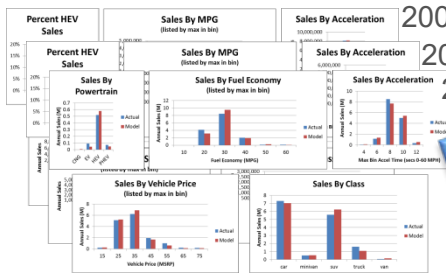
Approach

- Use ADOPT to estimate R&D energy and emission benefits
  - Improve model
  - Implement 2019 technical targets
  - Run No Program scenario
  - Compare to technology success scenarios

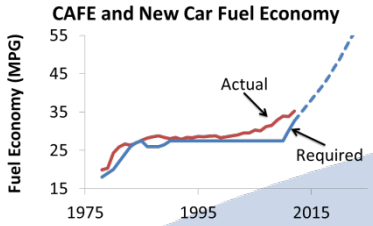
- Review results with VTO

- Discuss target updates and rerun as needed

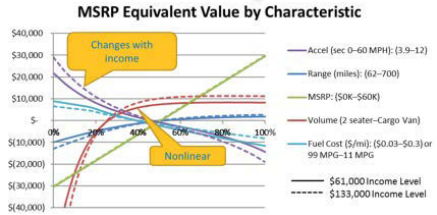
Approach: ADOPT



Validation

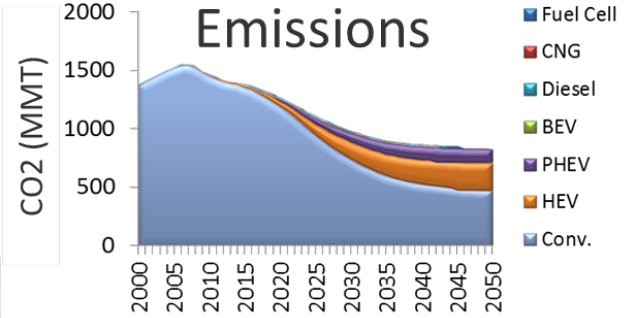


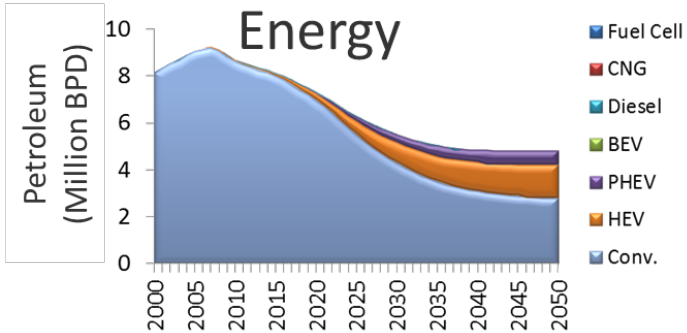
Policy



Consumer Preferences

Sales/Stock





1

All Existing Options

Evolve

3

Market Driven

2

Technical Targets

Future Options

FASTSim

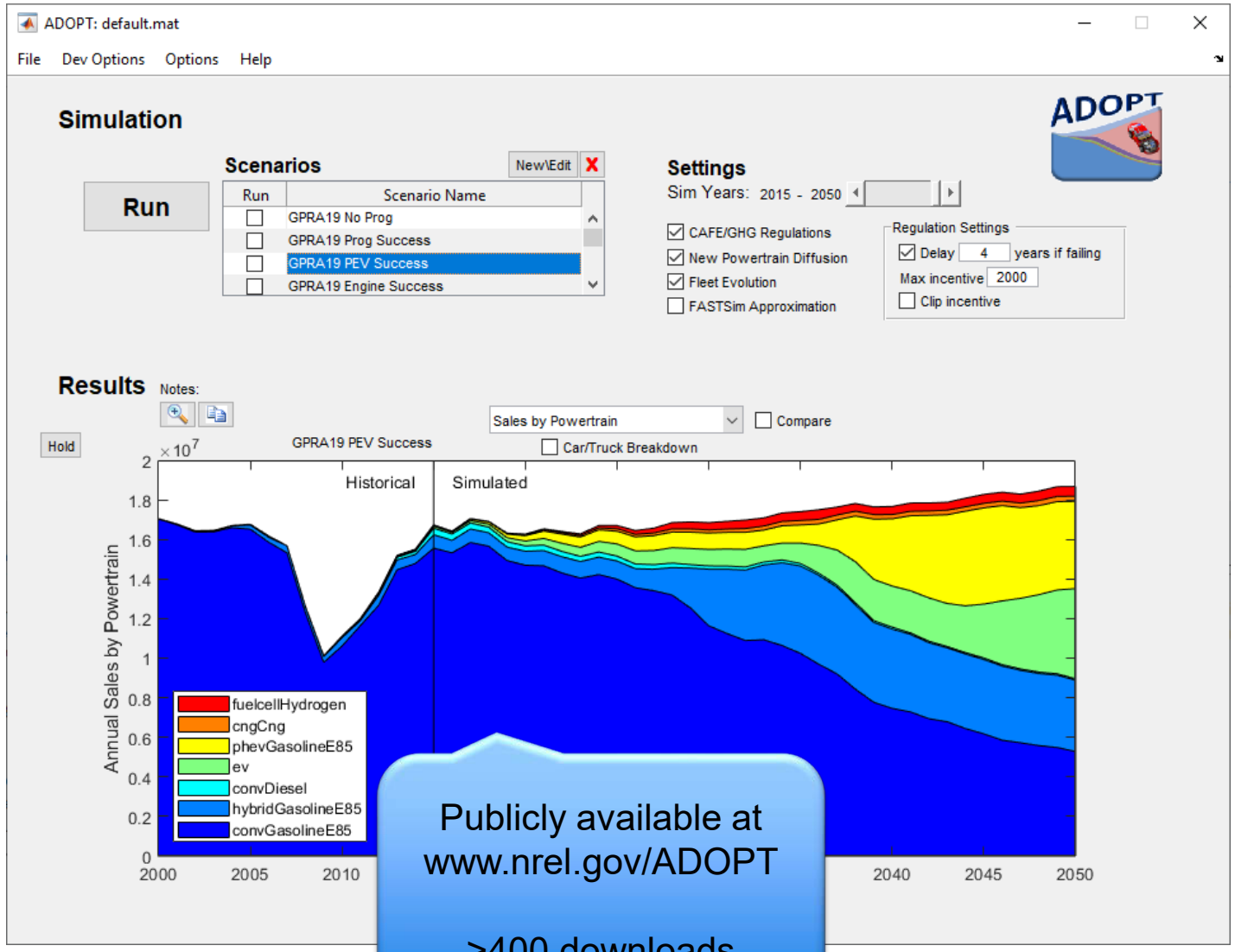
Images credits
1. D. Schroeder, NREL
2. Jim Snyder, NREL
3. San Joaquin Valley Clean Cities

CAFE: Corporate Average Fuel Economy
MSPR: Manufacturer Suggested Retail Price

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 combination of component sizes requires running the vehicle powertrain model Future Automotive Systems Technology Simulator (FASTSim) 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.

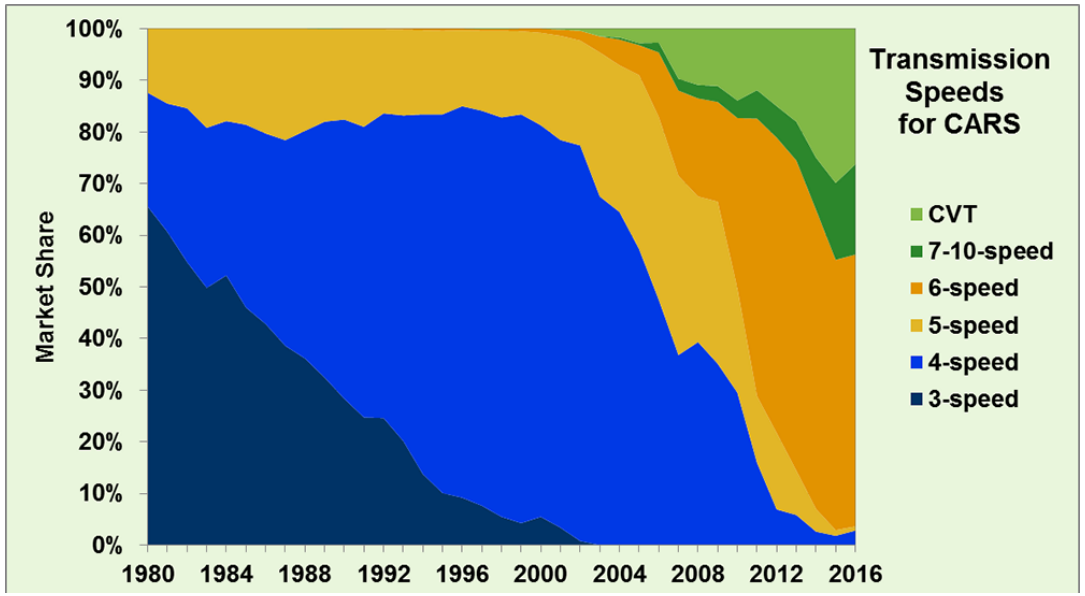


Publicly available at www.nrel.gov/ADOPT

>400 downloads

Accomplishment: Enhancements to Approach

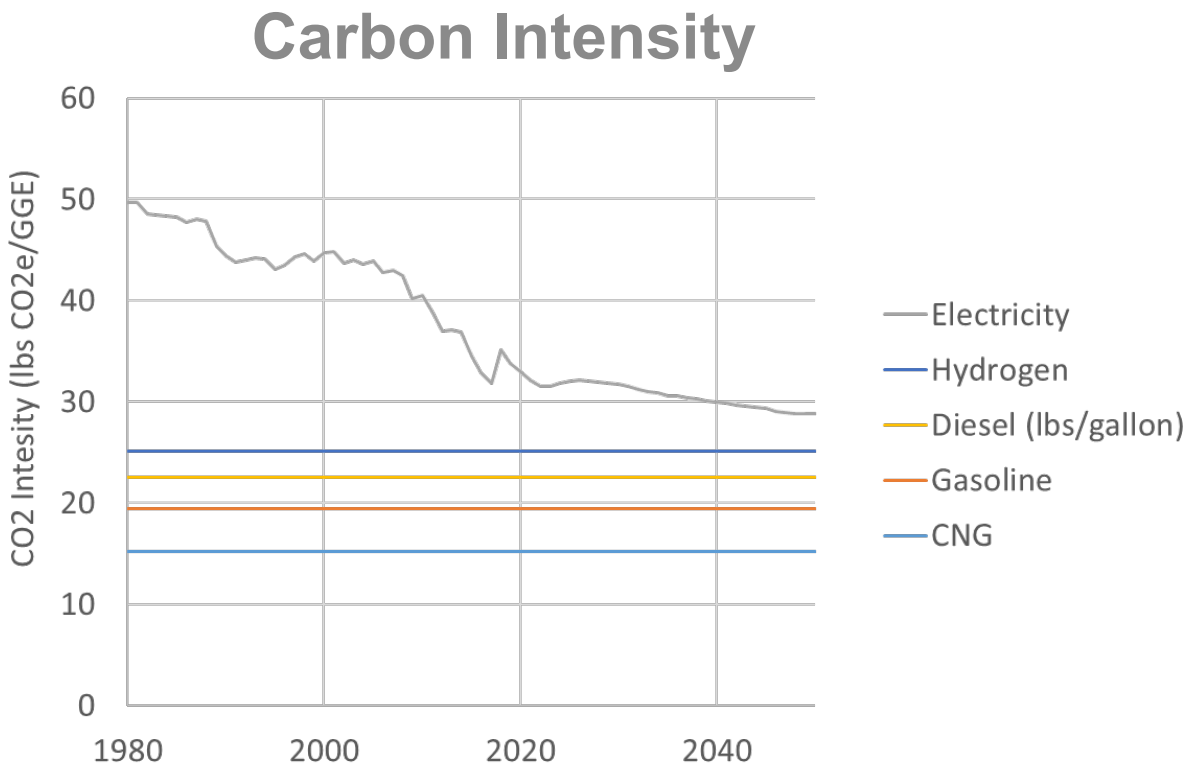
- Complete
  - Improved transmission modeling to capture trend of increasing number of speeds
  - Added automatic inflation adjustment to sync prices of different data sets
  - Improved long-distance range penalty for BEVs
- Ongoing
  - Home charging availability
  - Multivehicle household impact on BEV purchases

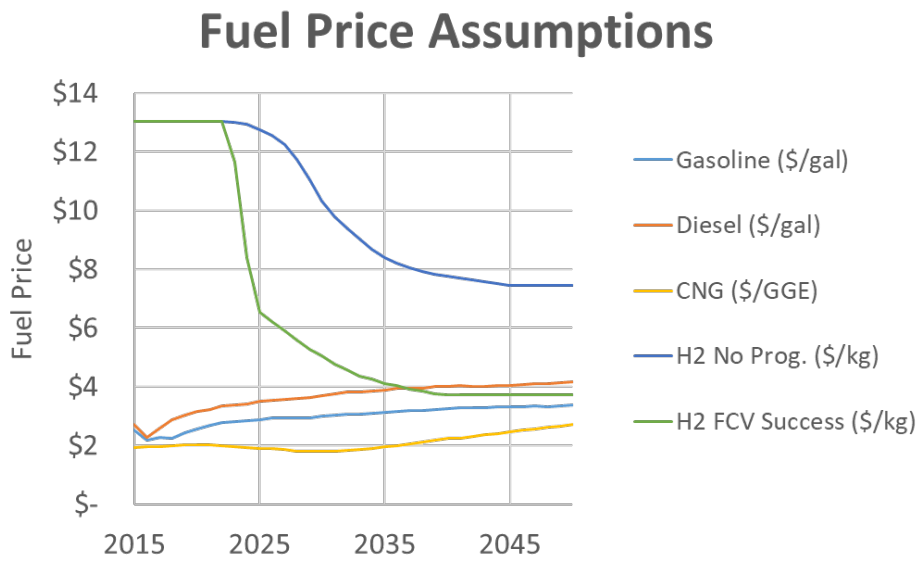


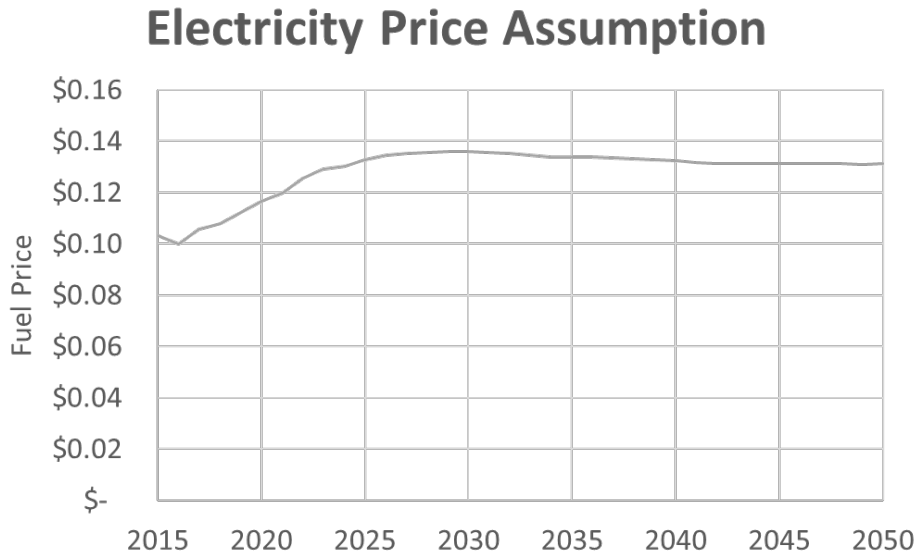
Source: Oak Ridge National Laboratory, *2016 Vehicle Technologies Market Report*, May 2017.

CVT: continuous variable transmission

Approach: Assumptions



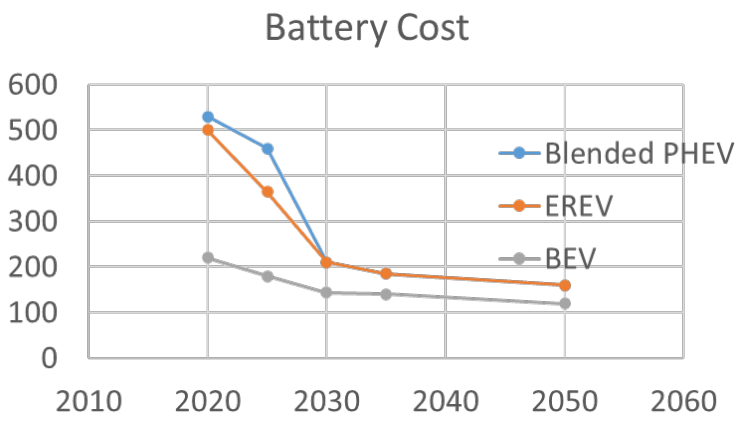


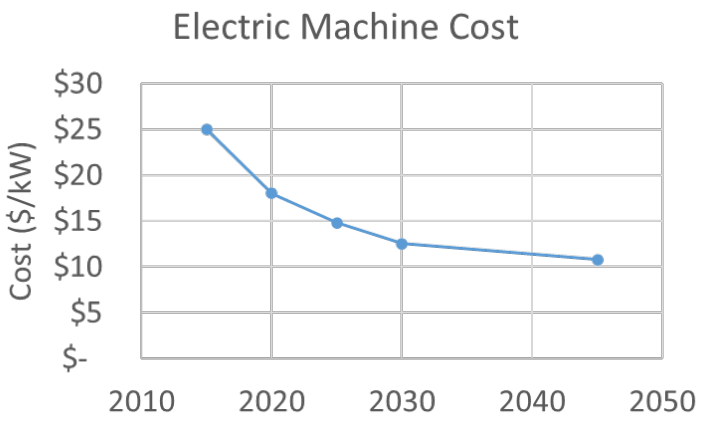


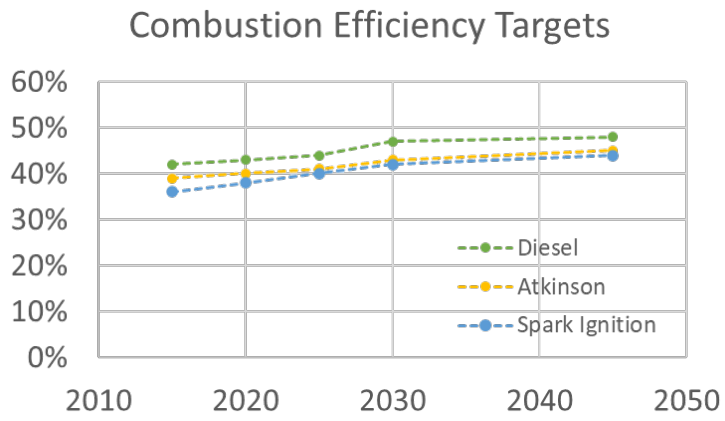
CO2e: carbon dioxide equivalent
FCV: fuel cell vehicle
GGE: gasoline gallon equivalent

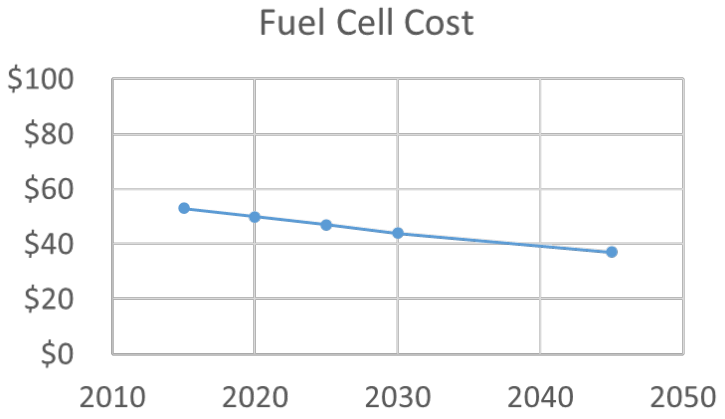
Annual Energy Outlook (AEO) reference oil price

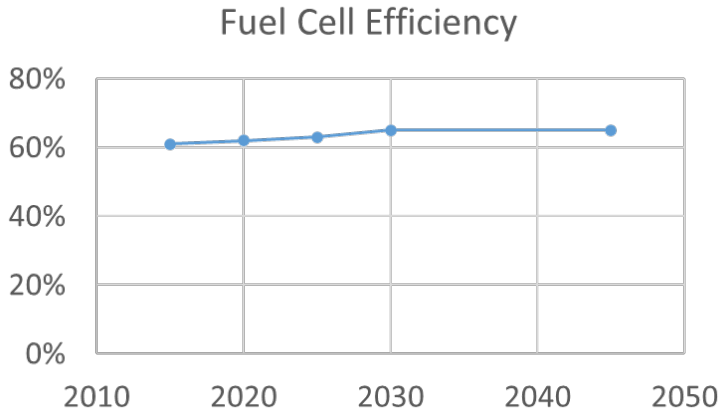
Approach: No Program Technical Target Assumption Highlights

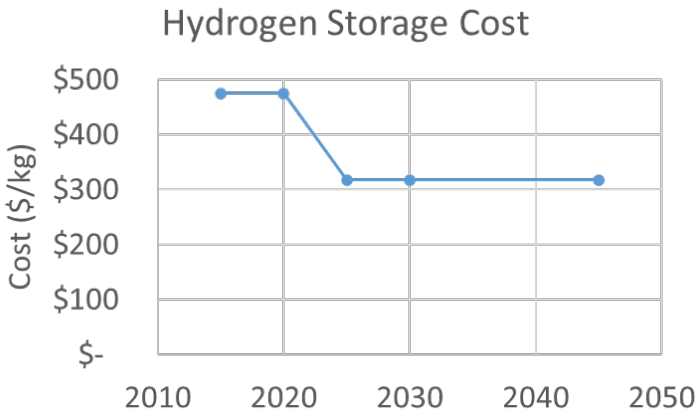








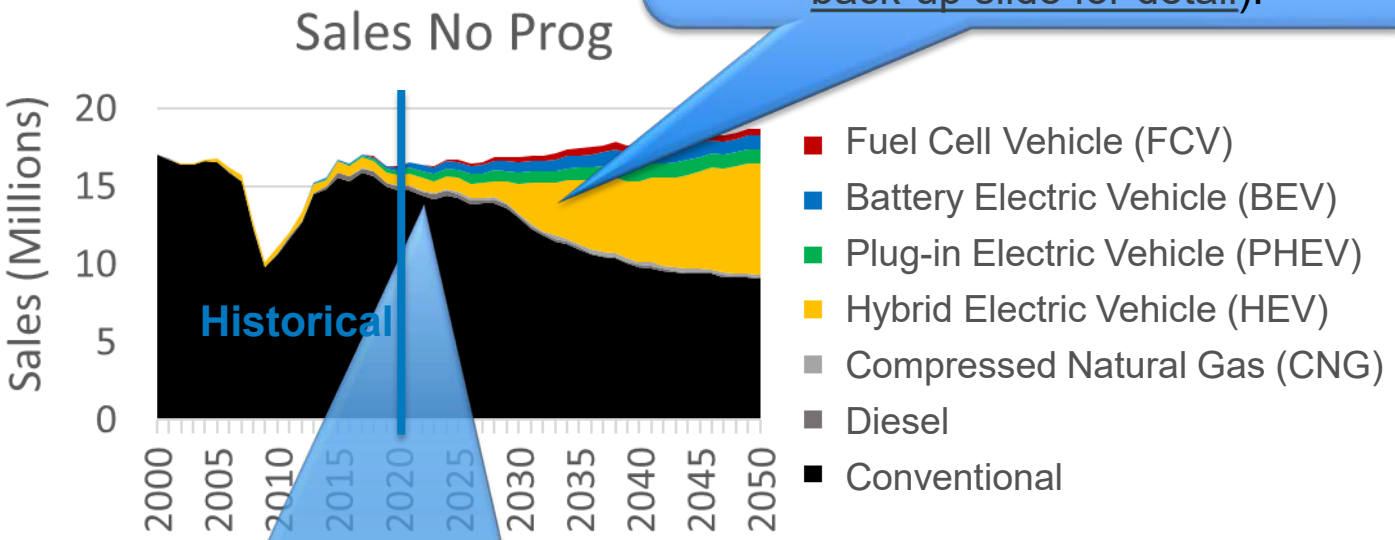




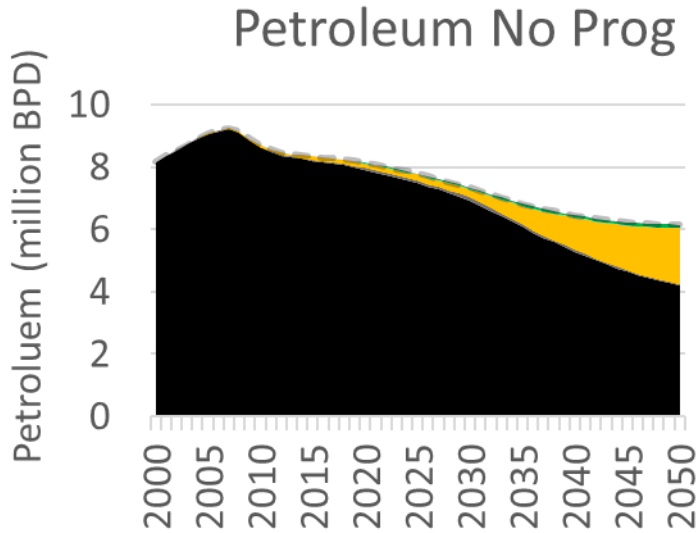
EREV: extended range electric vehicle

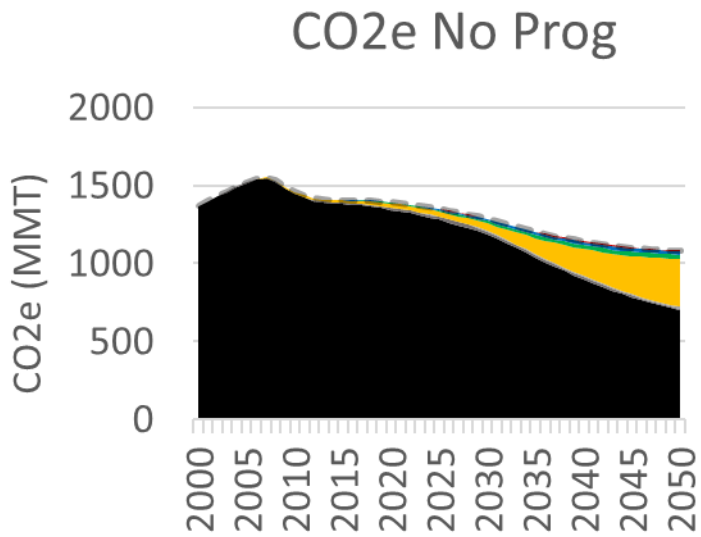
Accomplishment: No Program Results

HEVs later as battery cost drops enough to make performance options at mass market prices (see technical back-up slide for detail).



Near-term, most sales continue to be conventional vehicles because of their low price, reasonable acceleration, high range, and quick refueling (see technical back-up slides for details).





No Program
Program Success

Batteries	APEEM	Combustion	Materials	Fuel Cells	H2 Storage

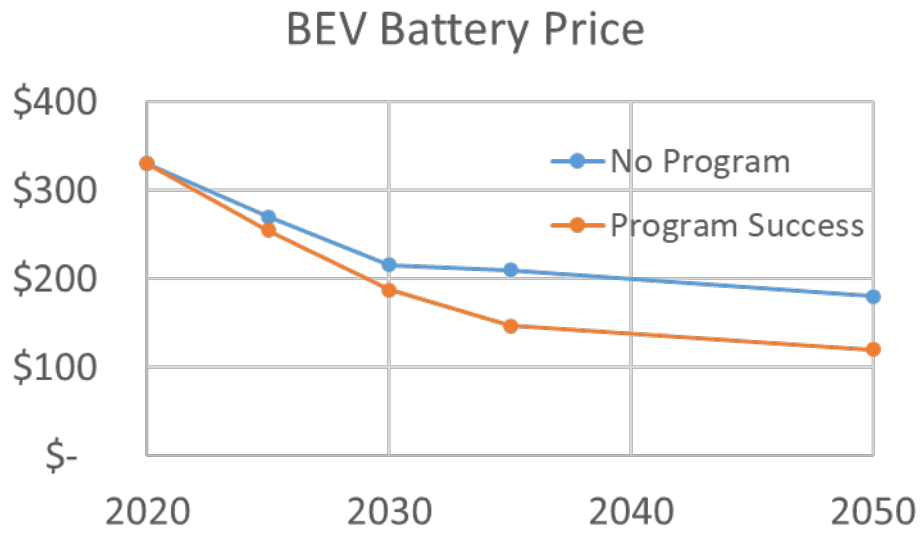
Electrification Success Using 2019 Assumptions

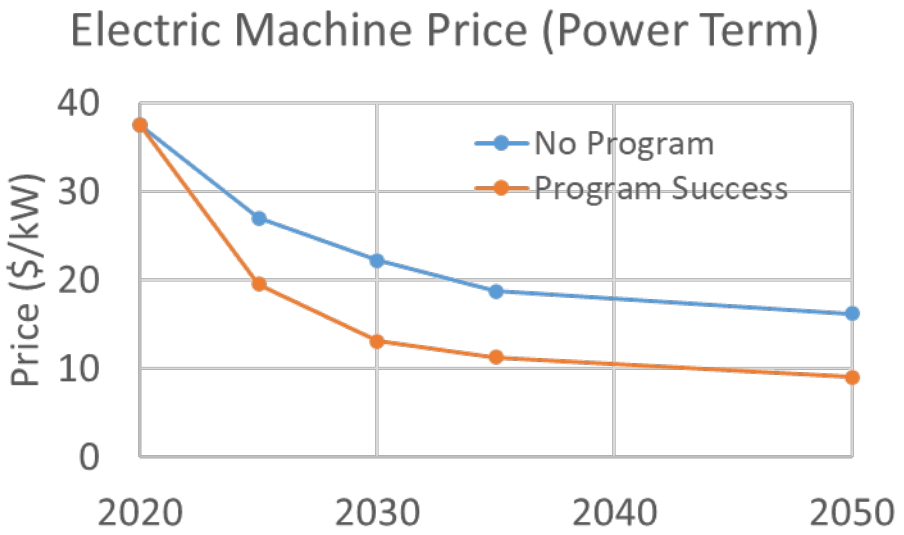
Technical Accomplishments and Progress

No Program						
Program Success	**Batteries**	**APEEM**	**Combustion**	**Materials**	**Fuel Cells**	**H2 Storage**

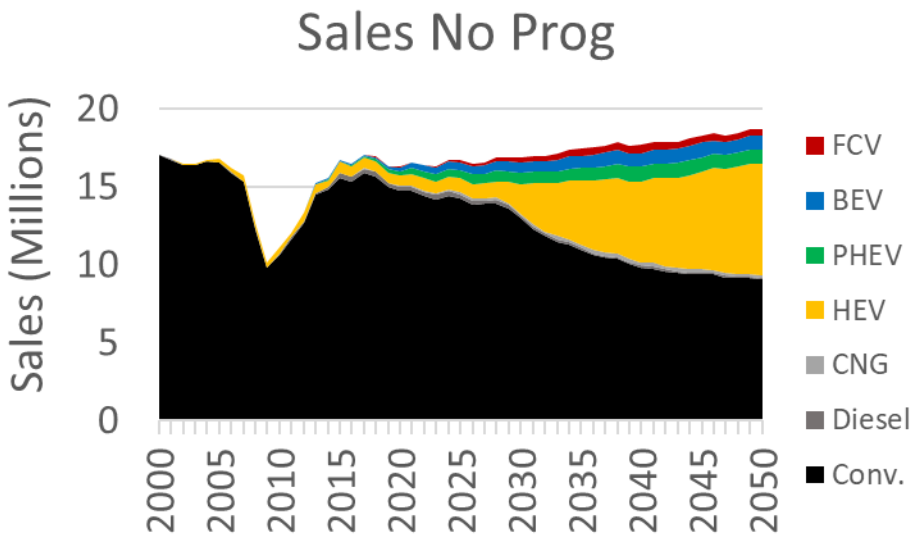
Approach: Electrification Target Highlights

To estimate sales:
Cost → Price (1.5x)
Lab Year → Market Year (+5)





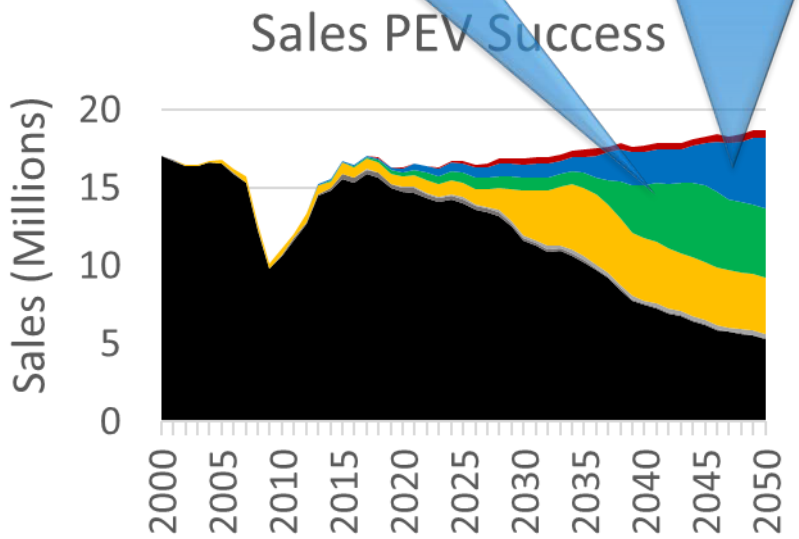
Accomplishment: Electrification Success Sales Comparison



HEVs first again, but then PHEVs as battery cost reaches $90/kWh and can provide quick acceleration at a mass market price (see technical back-up slides).

BEVs when battery cost reaches $80/kWh and they have good range and quick acceleration at a mass market price.

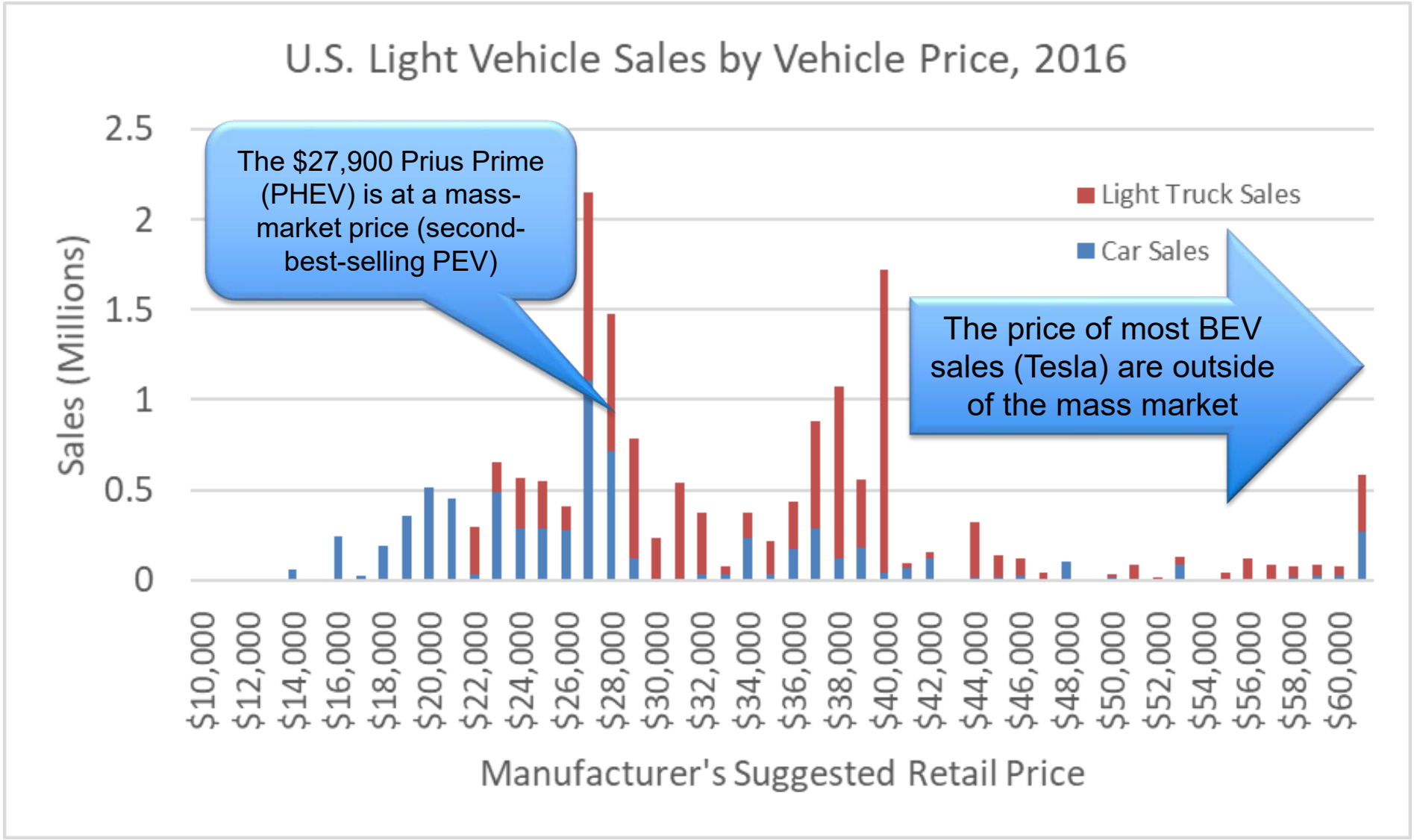
Electrification Success



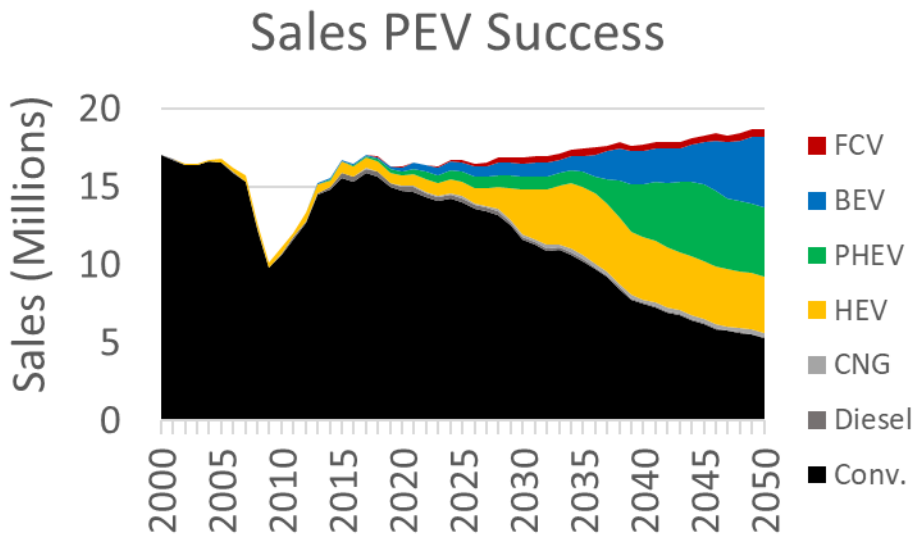
No Program
Program Success

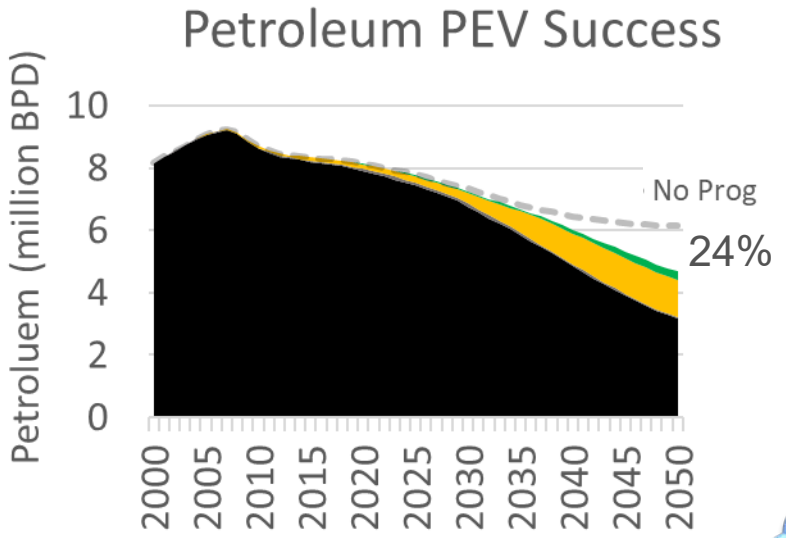
Batteries	APEEM	Combustion	Materials	Fuel Cells	H2 Storage

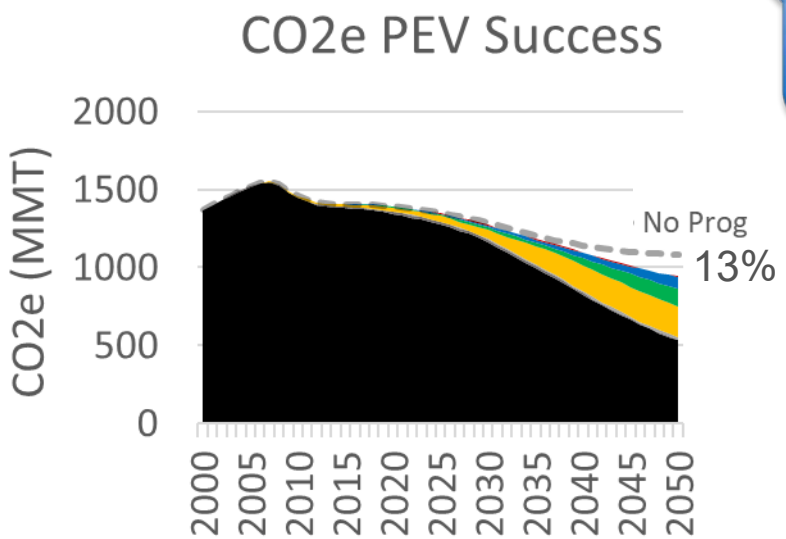
Accomplishment: PHEV Mass Market Potential Explanation



Accomplishment: Electrification Benefits Results





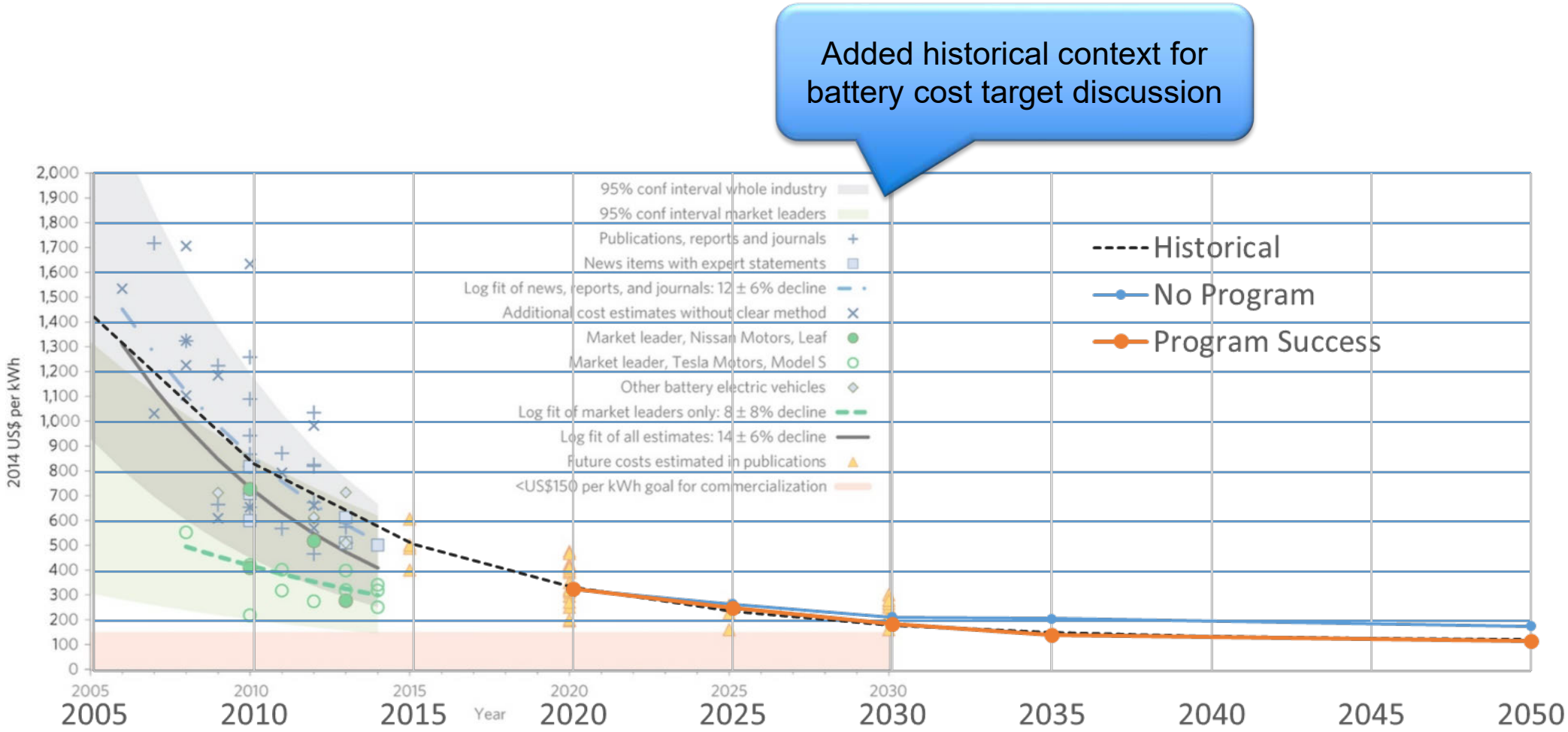


24% energy and 13% emission benefits

No Program
Program Success

Batteries	APEEM	Combustion	Materials	Fuel Cells	H2 Storage

Accomplishment: Added Historical Context



Nykvist, B. and Nilsson, M. 2015. "Rapidly falling costs of battery packs for electric vehicles." *Nature Climate Change* 5: 329–332. https://doi.org/10.1038/nclimate2564.

Responses to Previous Year Reviewers' Comments

Constructive comments from last review of this project (performed by another lab)

- "…it would be useful to look at program success scenarios one at a time for individual technology/subprogram targets…"
  - Implemented to show the value of each technology area, and the program robustness
- "…identify whether additional synergies may exist within the program investments."
  - We ran scenarios (most not shown) that evaluate potential synergies, such as including material success with electrification (was not synergistic because it helps conventional vehicles more)
- "…explore sensitivity to fuel costs also seems critical…"
  - Included in next steps

Collaboration and Coordination with Other Institutions

- Working with ANL (Thomas Stephens)
  - ANL provided useful background knowledge, experience, previous technical targets, and results
  - Compared sales and benefits results
  - Updated analysis based on their input and feedback
- Ongoing meetings with VTO technology managers to discuss
  - 2019 targets and benefits results
  - Updates to those targets
- Technology managers interface with industry for input on targets

Remaining Challenges and Barriers

- Capturing home charging availability
  - Most households have home charging, but not all
  - Need to capture additional cost for those that do not
- Breaking out preferences for multivehicle households
  - A second, longer-range vehicle may reduce penalty for shorter-range BEVs
- Considering changes to transportation and household paradigms
  - How significant are the trends in telecommuting (now with COVID-19)?
  - Are household income projections changing?

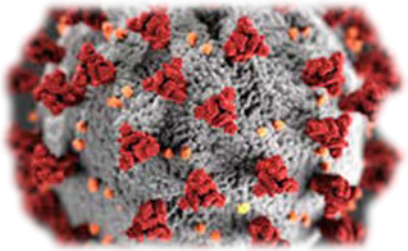
Proposed Future Research

FY 2020 (ongoing)

- Review 2019 targets and results with VTO technology managers
- Discuss target updates for 2020
- Complete ADOPT updates, including:
  - Latest AEO input assumptions and fuel price sensitivities
  - Home charging availability
- Complete additional run/reviews iterations with tech managers
- Q4: Milestones
  - Deliver completed LD Benefits Analysis Report for final DOE review
  - Go/No-Go: Assess priorities for year two; Input assumptions and model updates

FY 2021

- Update with new input assumptions
  - AEO **fuel prices** – expect significant changes
  - AEO emissions
  - Changes in vehicle regulations (incentives, CAFE, Greenhouse Gas Standards)
- Complete additional ADOPT updates to improve accuracy and value of benefits estimates
  - Multivehicle household impact on BEV purchases
  - Account for transportation related shifts (more **telecommuting** from COVID-19, changes in **household income** projections)
  - Feedback from tech managers and this review

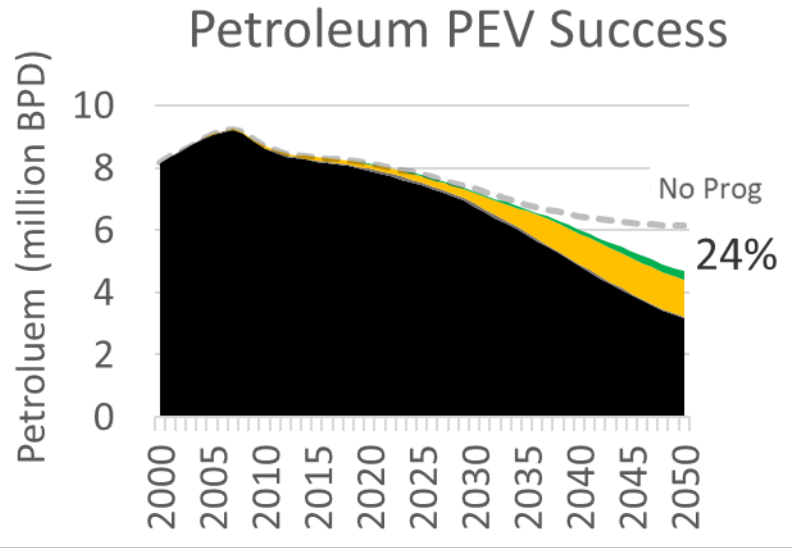


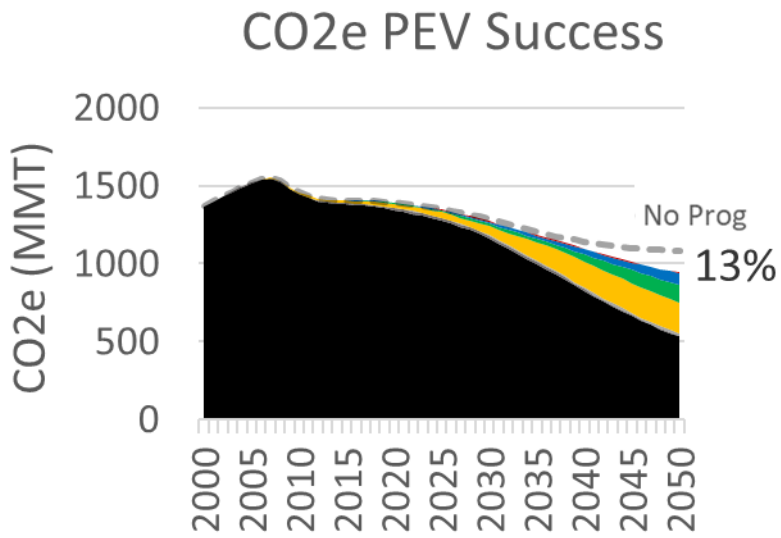
https://www.state.gov/coronavirus/

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

Summary

- Updated ADOPT
  - Used a well structured and efficient modeling approach (ADOPT)
  - Completed model enhancement to improved accuracy
  - Implemented 2019 technical targets
  - Ran No Program scenario
  - Compared to technology success scenarios
- Estimated significant annual energy and emission benefits. By 2050:
  - Electrification R&D success (Batteries & APEEM)
    - —24% energy
    - —13% emission
  - Also completed combustion & materials R&D success
    - —9% energy
    - —10% emission
- Found historical data to support target updates
- Next steps
  - Discuss 2020 updates with VTO technology managers
  - Add sensitivity analysis, such as variations in fuel prices
  - Complete additional run/reviews iterations with tech managers





Thank You

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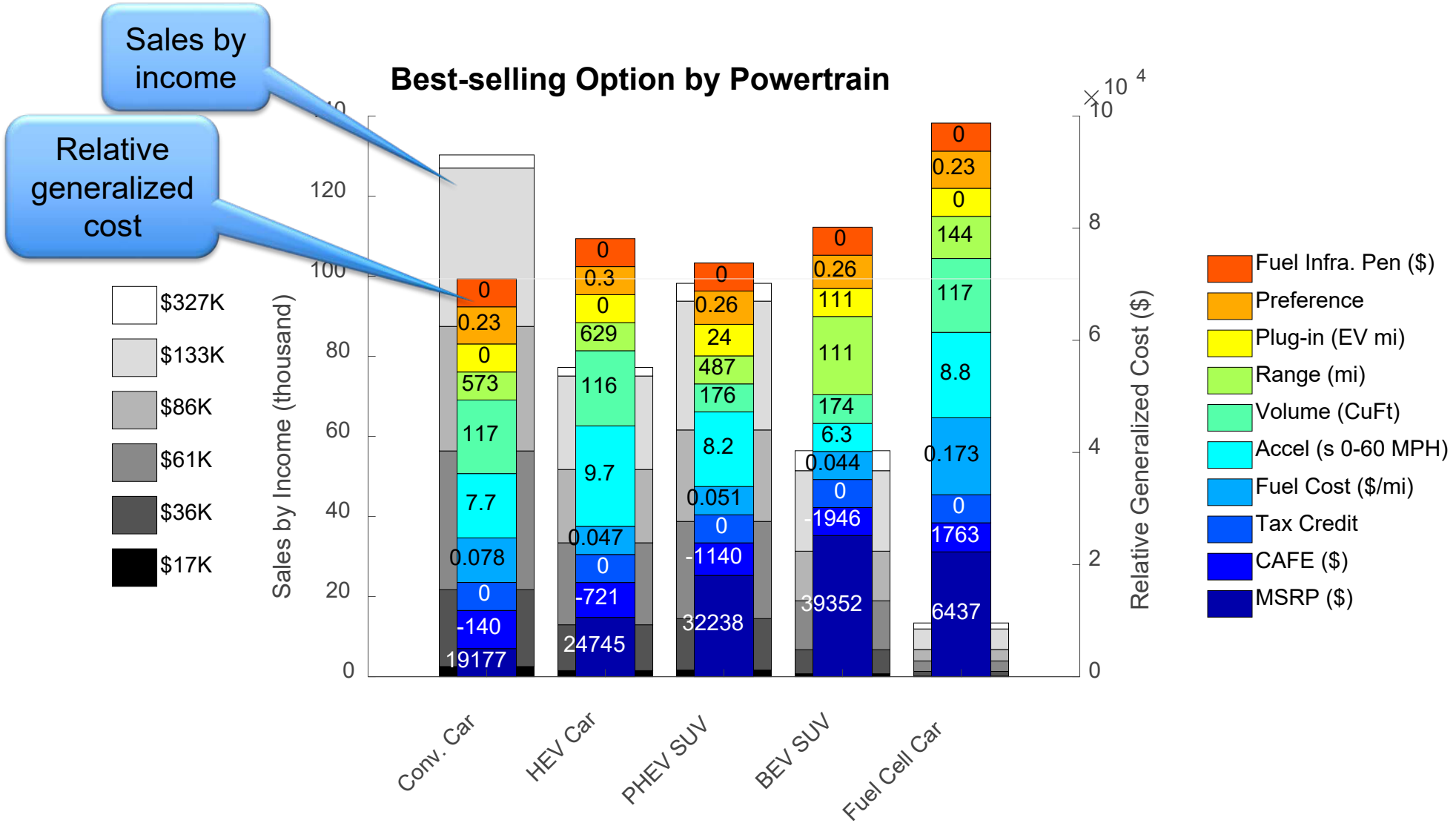
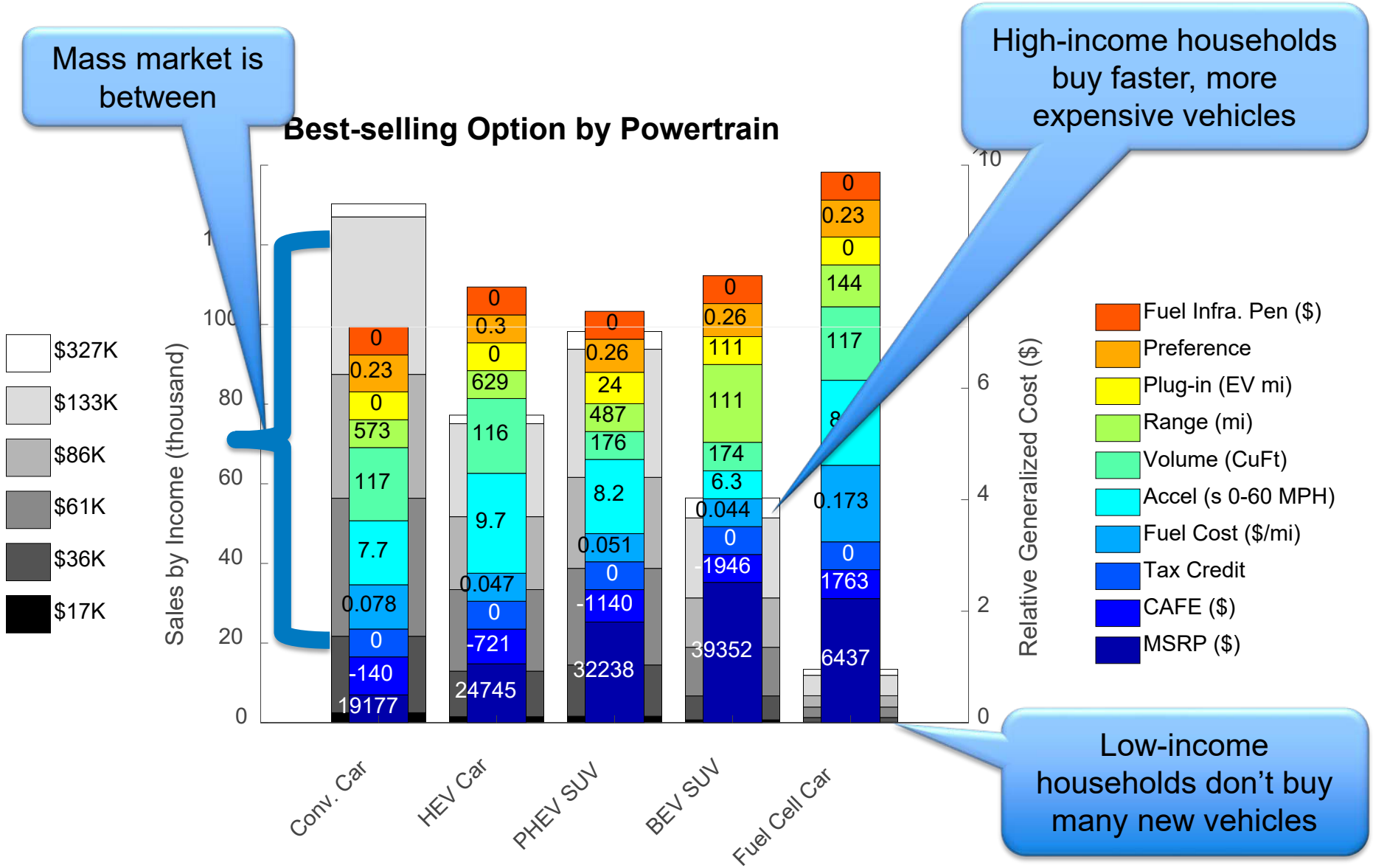
Technical Back-Up Slides

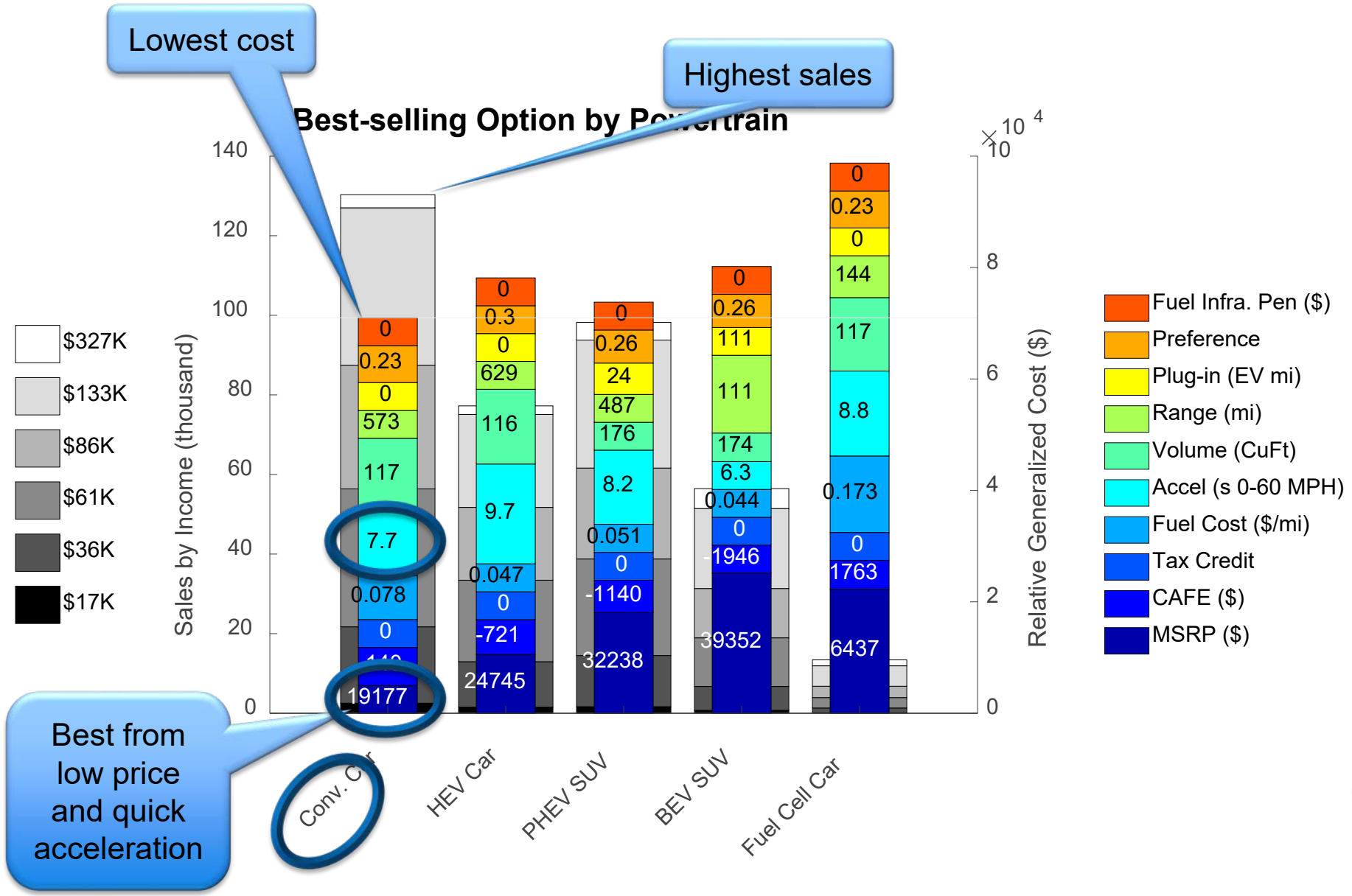
Accomplishment: 2020 Sales Explanation



Accomplishment: 2020 Sales Explanation – Income



Accomplishment: 2020 Sales Explanation



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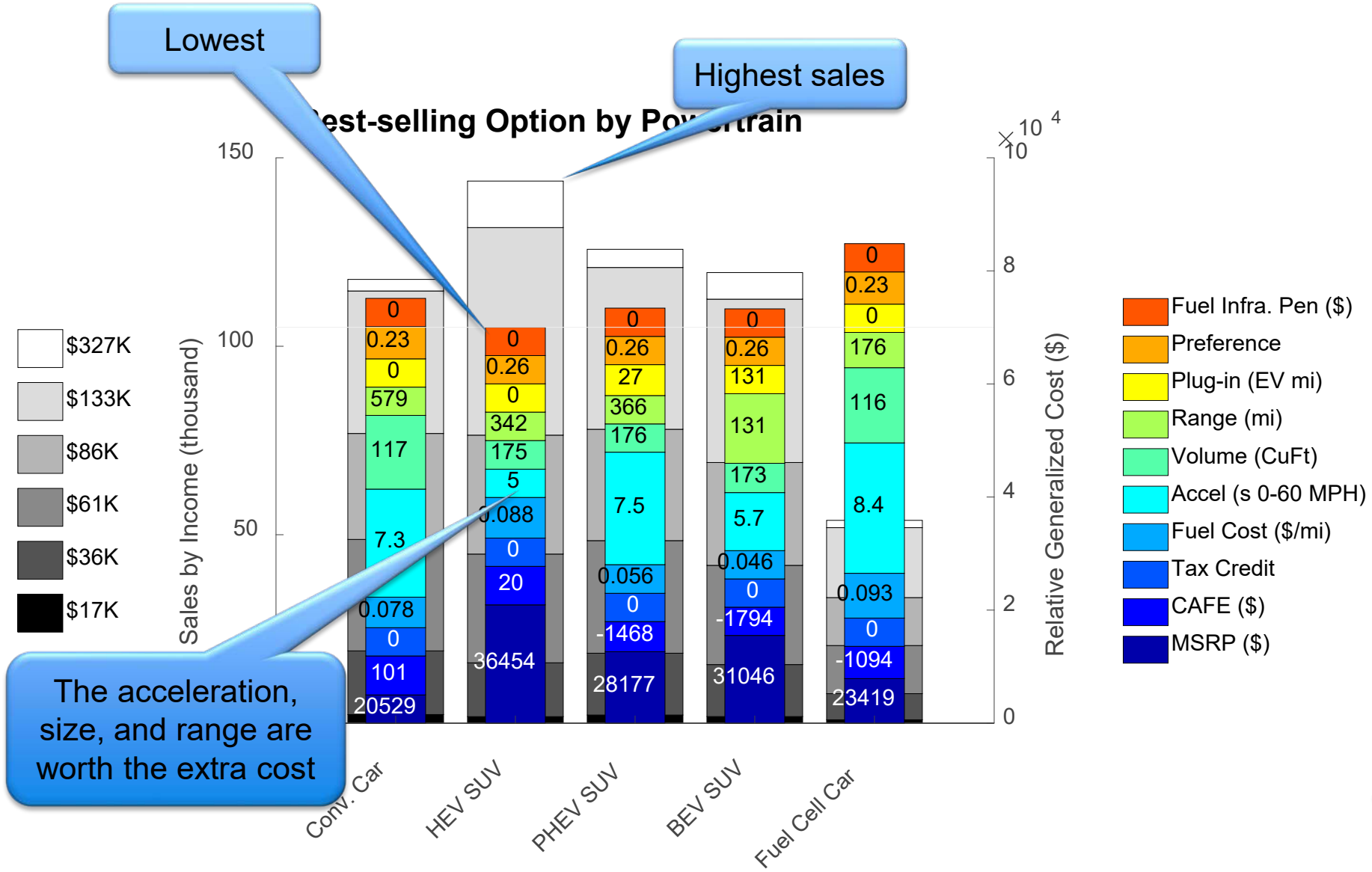
Accomplishment: 2040 HEV Sales Explanation



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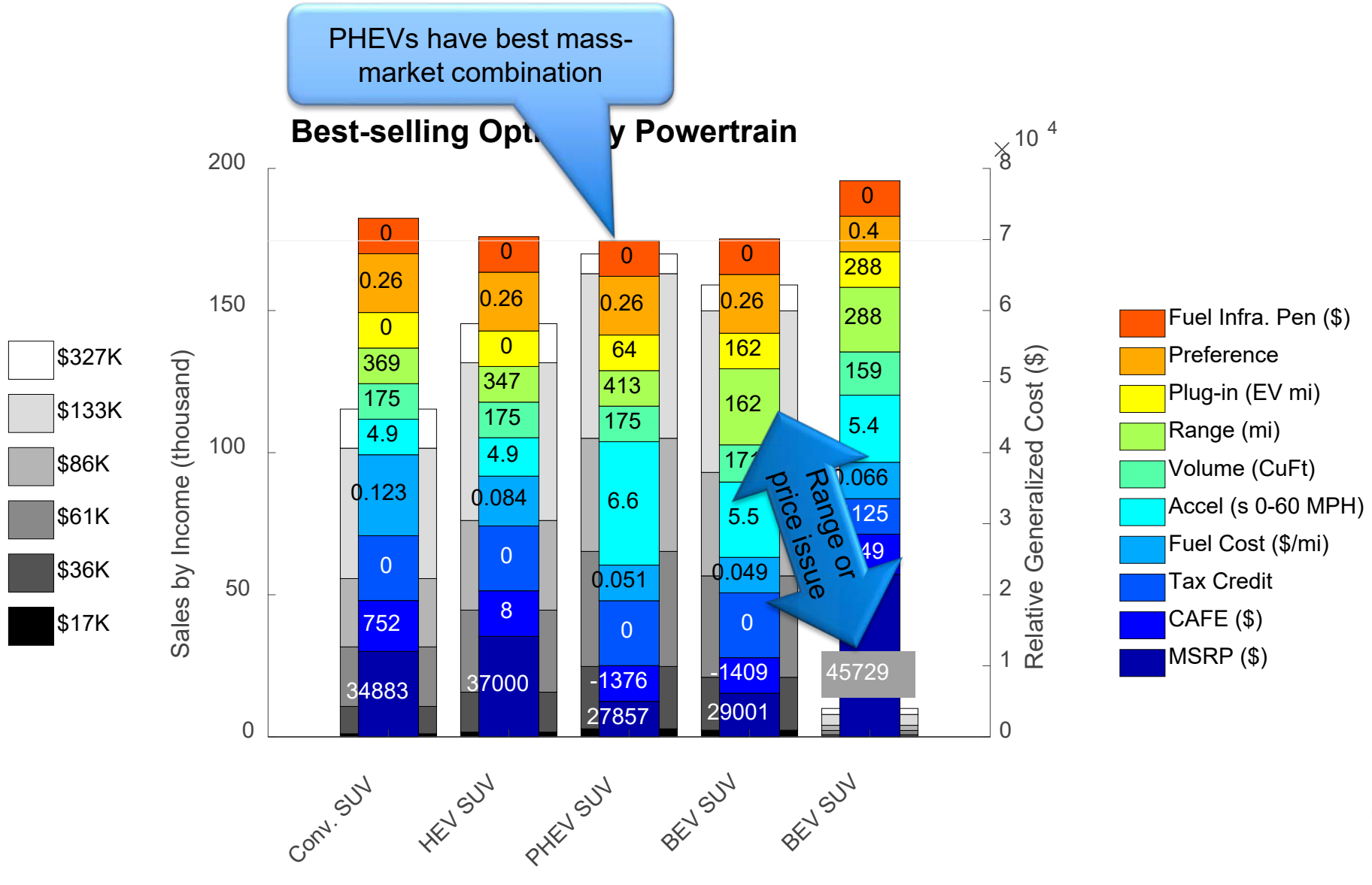
Accomplishment: 2035 PHEV Sales Explanation – Income



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