Impact Analysis: VTO Baseline and Scenario (BaSce) Activities

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2015 Vehicle Technologies Annual Merit Review

June 11, 2015

Project VAN001

Overview

Timeline

- Ongoing Project

Budget

- FY14: $630k
  - Includes TA Engineering
- FY15: $495k
  - Includes TA Engineering, Navigant Research

Barriers

- Complexity of relationship between component-level technologies and national-level performance and benefits
- Need for synthesis of VTO modeling, data, and analysis activities

Partners

- Interactions / Collaborations
  - Argonne National Lab (VAN002, -006, -008)
  - Oak Ridge National Lab (VAN005)
  - National Renewable Energy Lab (VAN004)
  - Sandia National Lab (VAN014)
  - TA Engineering, Inc.
  - Energetics, Inc.
  - Navigant Research
  - German Aerospace Center
  - Fraunhofer Institute

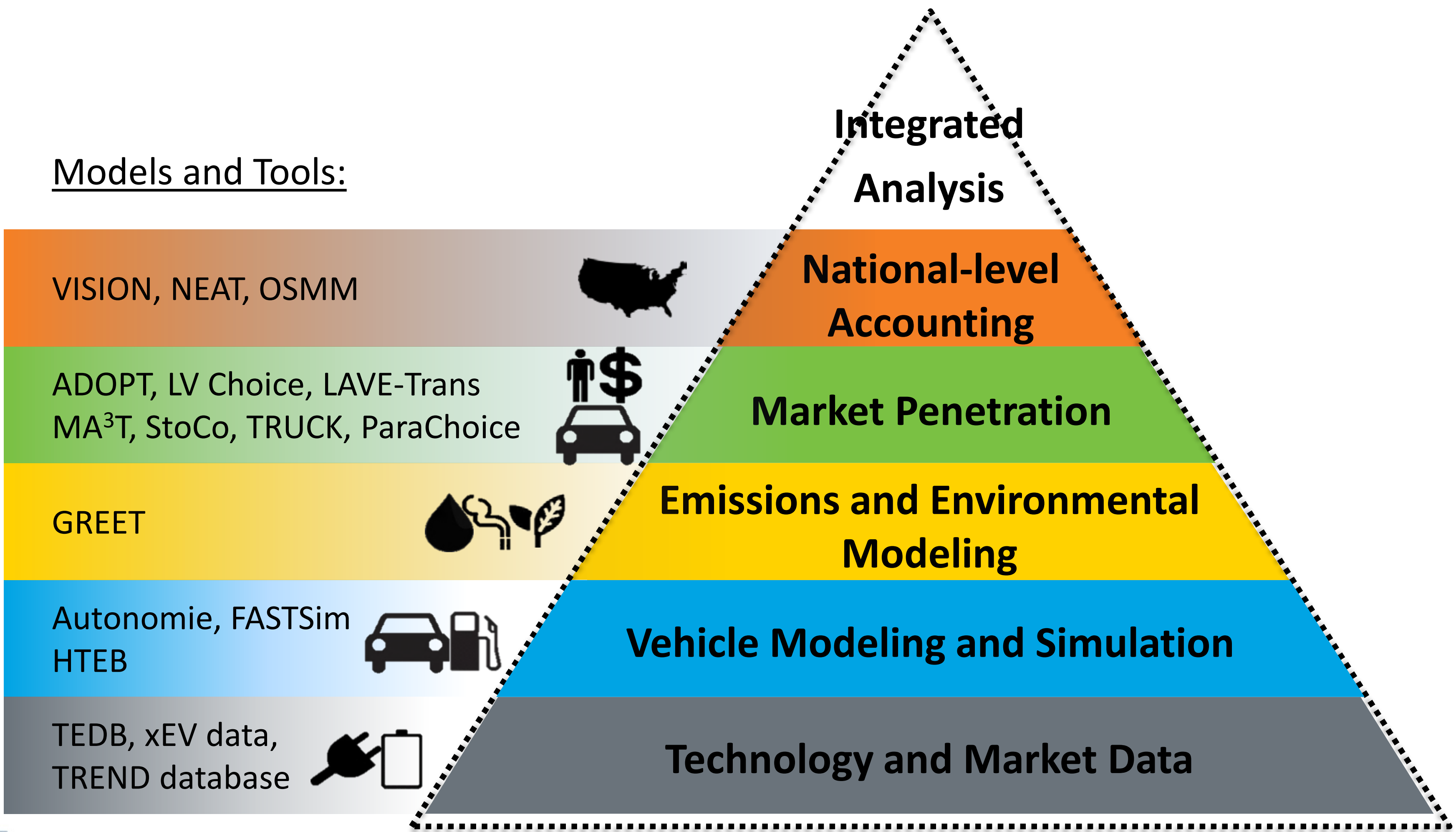
Objectives and Relevance

- Objective: Estimate the potential future benefits of the EERE Vehicle Technologies Office (VTO) program at the national level. Benefits estimated include
  - Petroleum savings
  - GHG emissions reduction
  - Levelized cost of driving (light duty vehicles)

- Relevance: Link projected reductions in petroleum use and GHG emissions to VTO technical areas:
  - Batteries and electric drive
  - Materials (Mass reduction)
  - Advanced combustion engines
  - Fuels and lubricants
- Informs VTO Program Managers about impacts of achieving technology program targets, e.g., EV Everywhere Grand Challenge
- Provides input to EERE Corporate portfolio benefits analysis
- Used for EERE Program Records

BaSce is the "capstone" of VTO analysis activities

- Integrates data, modeling, and analyses from the VTO Analysis portfolio to assess potential benefits of VTO technologies



Milestones

Month / Year	Description	Status
Oct 2014	Define assumptions and vehicle parameters	Complete
Nov 2014	Establish baseline case	Complete
Dec 2014	Complete initial vehicle modeling[1, 2]	Complete
Jan 2014	Complete initial market penetration analysis	Complete
Feb 2014	Revise vehicle and market penetration analyses	Complete
Feb 2014	Complete fleet-level analysis and estimate benefits by technology area	In progress
Apr 2015	Issue final benefits report	In progress
Sep 2015	Complete report documenting recommended practices for scenario analyses (levelized cost, fuel economy adjustment)	In progress

[1]Light-duty vehicle simulations performed by ANL Autonomie Team (see #VAN008)

[2]Heavy trucks analyzed by TA Engineering using HTEB and TRUCK models

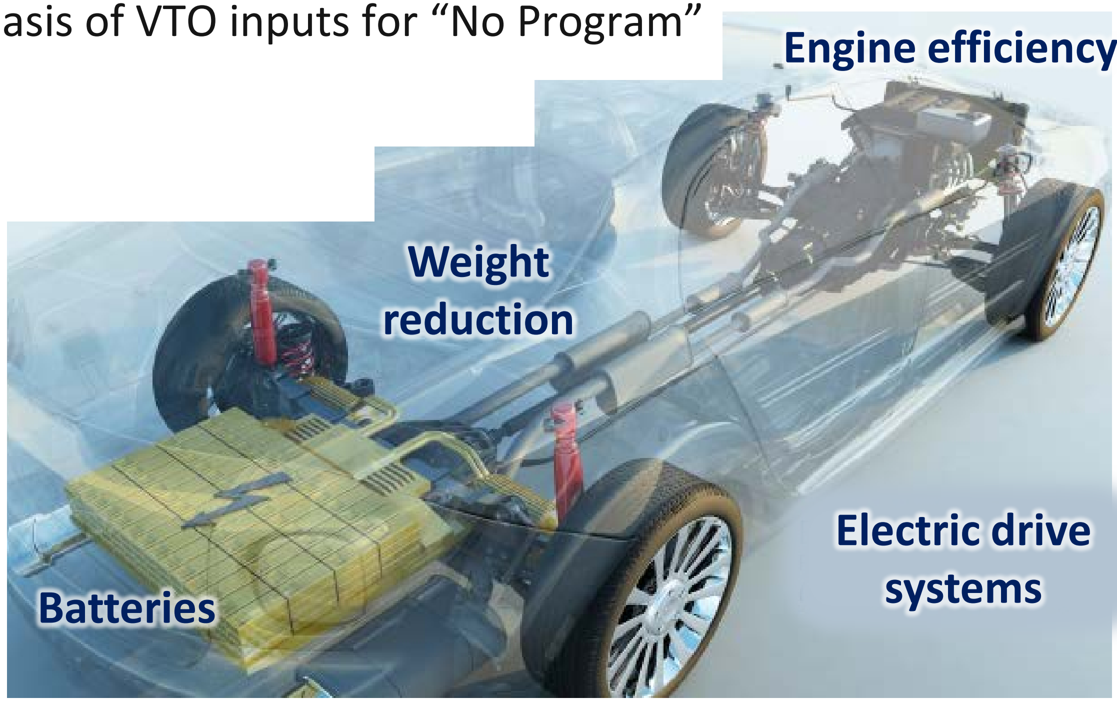
Approach: Compare two scenarios, with and without successful deployment of VTO Technologies

- Program Success: Vehicles meet VTO performance, fuel economy and cost targets
  - Vehicle component cost and performance based on VTO program targets, projected to 2050
  - Vehicle attributes estimated from component attributes
- Baseline (No Program): Without VTO technology improvements
  - Vehicles simulated on the basis of VTO inputs for "No Program"

VTO targets for subprograms:

- **Electric drive and batteries**
- **Adv. combustion engine R&D**
- **Materials R&D**
- **Fuels and Lubricants R&D**

For light-duty and heavy-duty vehicles



Approach: Components ➔ Vehicles ➔ Fleet

- **Component-level attributes**: VTO targets, and inputs from VTO PMs, ANL and industry experts
- **Vehicle simulations**: Estimate vehicle attributes, including price, fuel economy, etc. (LDVs: Autonomie; HDVs: HTEB model)
- **Market penetration, levelized cost**: Estimate sales shares by vehicle class and drivetrain type (LDVs: MA^{3}T, LVChoice, others; HDVs: TRUCK)
- **Stock model**: Calculate fleet stock, fuel use and GHGs (VISION model, and coefficients from GREET^{TM})
- **Attribute benefits to technology areas**: Based on estimated contribution to reduction in fuel/mi by technology

Autonomie: Vehicle simulation tool (ANL)
HTEB: Heavy Truck Energy Balance model (TA Engineering)
MA^{3}T: Market Acceptance of Advanced Automotive Technologies (ORNL)
LVChoice: Light-duty vehicle choice model (Energetics, Inc.)
TRUCK: Heavy truck market penetration model (TA Engineering)
VISION: Stock/energy/Emissions accounting model (ANL)
GREET: Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model

Drivetrains/vehicle classes

LDV (Car and Light truck):
- SI Conv (Gasoline, CNG)
- CI Conv
- HEV (SI gasoline, SI CNG, and CI)
- PHEV
- BEV
- FCV

Med and Heavy duty vehicles (Class 4-6, 7&8 Single Unit, 7&8 Combination):
- Best-In-Class CI Conv
- Advanced CI
- Parallel HEV CI

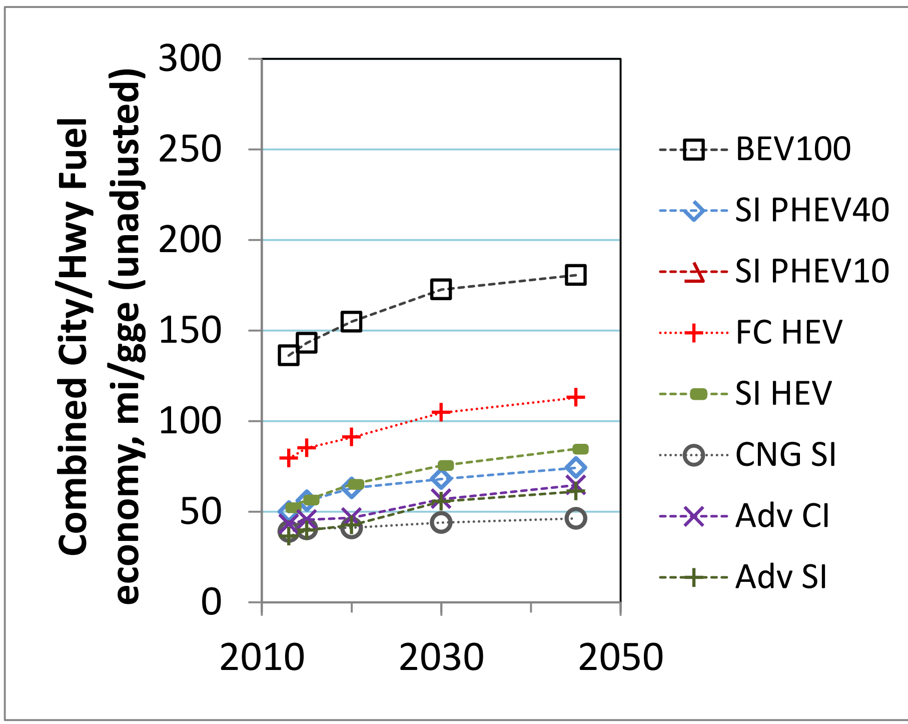
Assumptions

- AEO2013 High Oil Price fuel prices, H_2 price from FCTO (no price elasticity)
- Little public infrastructure for PEV charging, alt fuels, no biofuels (except for ethanol in E10)
- Annual VMT per vehicle as projected in AEO, with:
  - Slight elasticity for LDVs
  - HTs modeled by VMT "cohorts", based on 2002 VIUS
- GHG coefficients and upstream energy coefficients estimated from GREET™
- Energy and GHGs from vehicle production, scrap, recycle not included
- U.S. electricity generation mix as in AEO2013

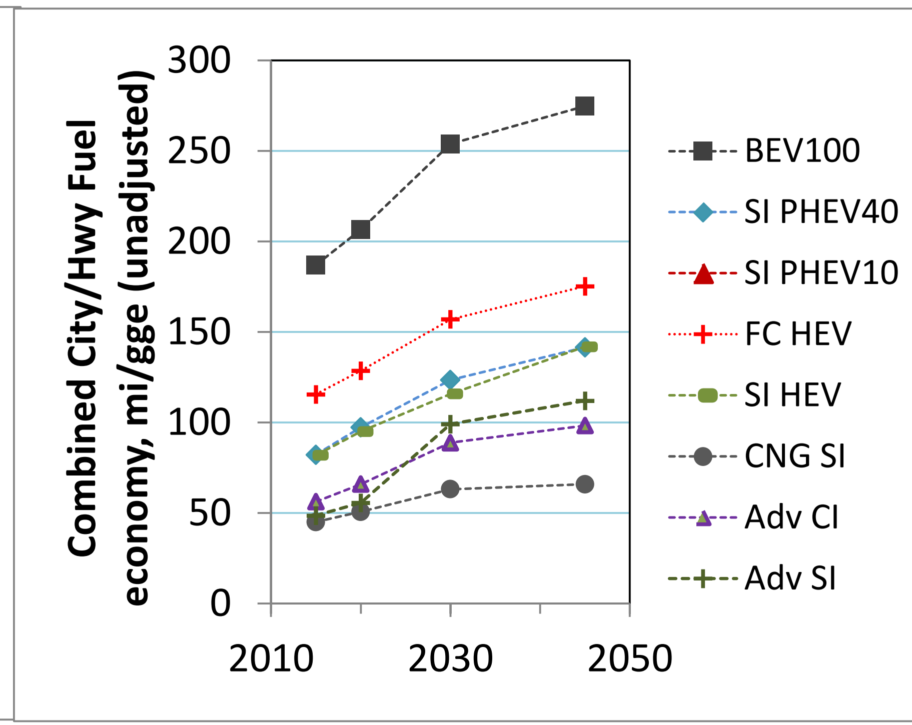
Significant improvement in fuel economy across all powertrain types in the Program Success case

- Vehicles simulated in UDDS and HWFET drive cycles
- Combined city/highway (55/45), unadjusted values shown

No Program case

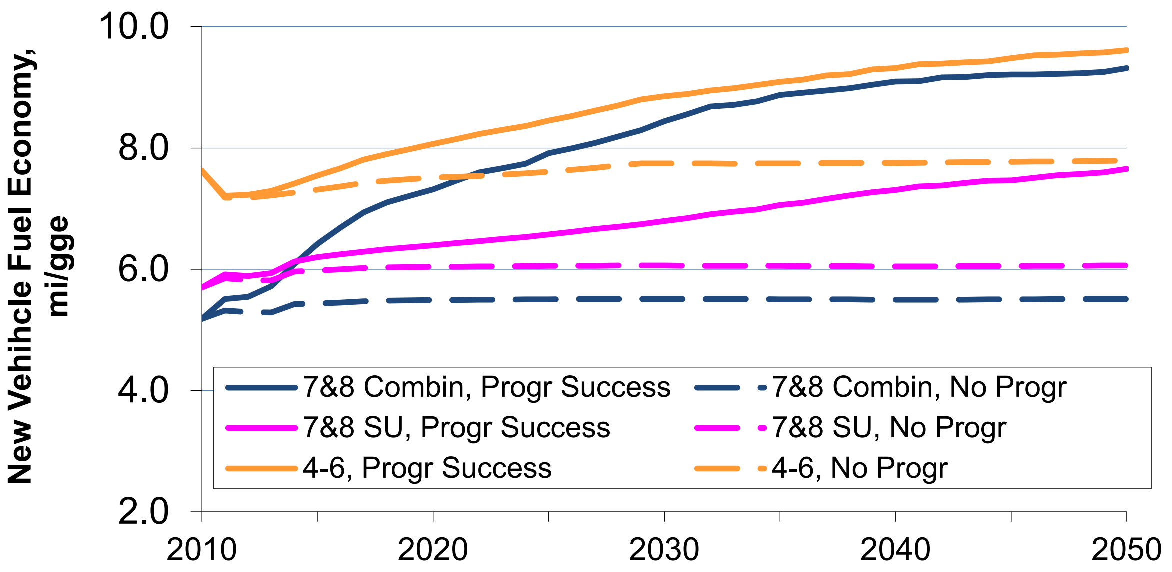


Program Success case



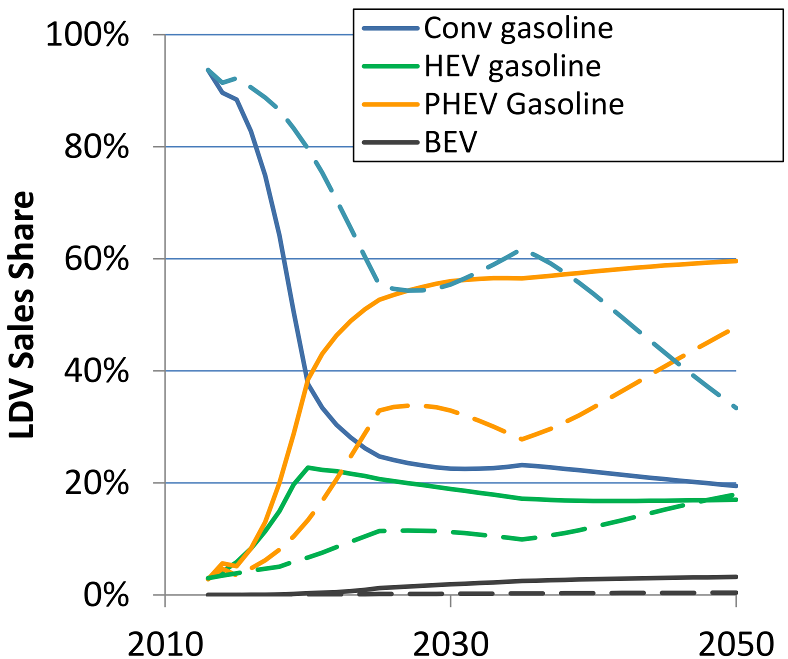
Also large improvements in heavy- and medium-duty fuel economy in the Program Success case

- Class 7&8 Combination truck fuel economy is projected to increase much faster in the Program Success case
- Fuel economy technologies “spill over” into Medium-duty (Class 4-6)

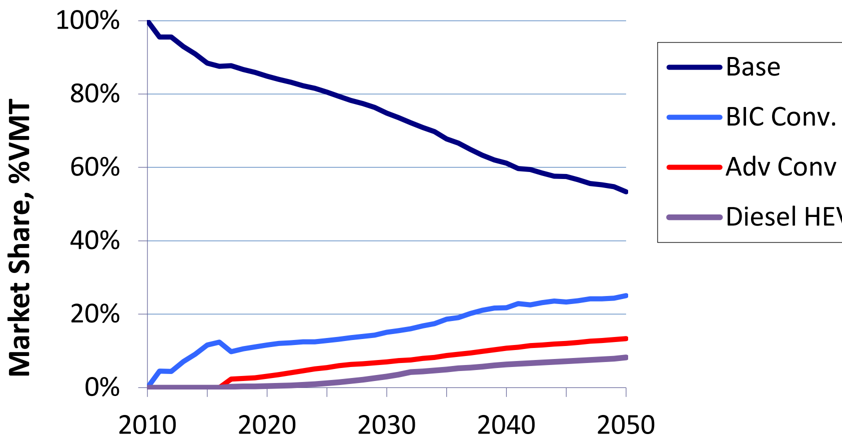


Accomplishment: Projected market penetration

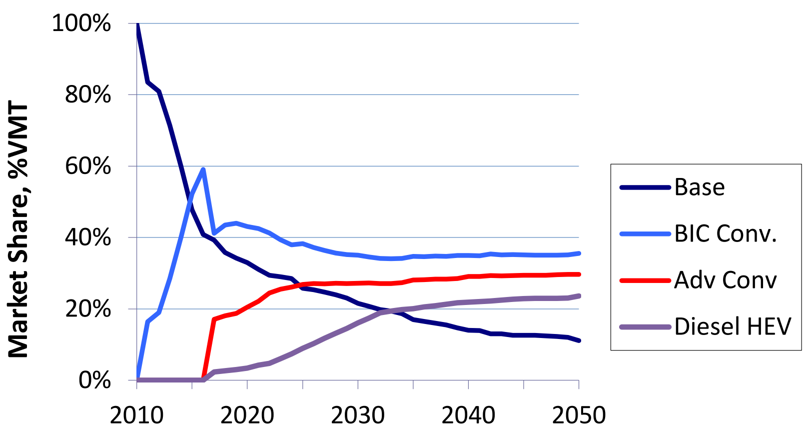
- VTO Success cases show rapid penetration by advanced technologies
- Little penetration of BEVs or FCVs in these cases (little public charging or hydrogen infrastructure assumed)



Market Penetration, Class 7&8 Single Unit

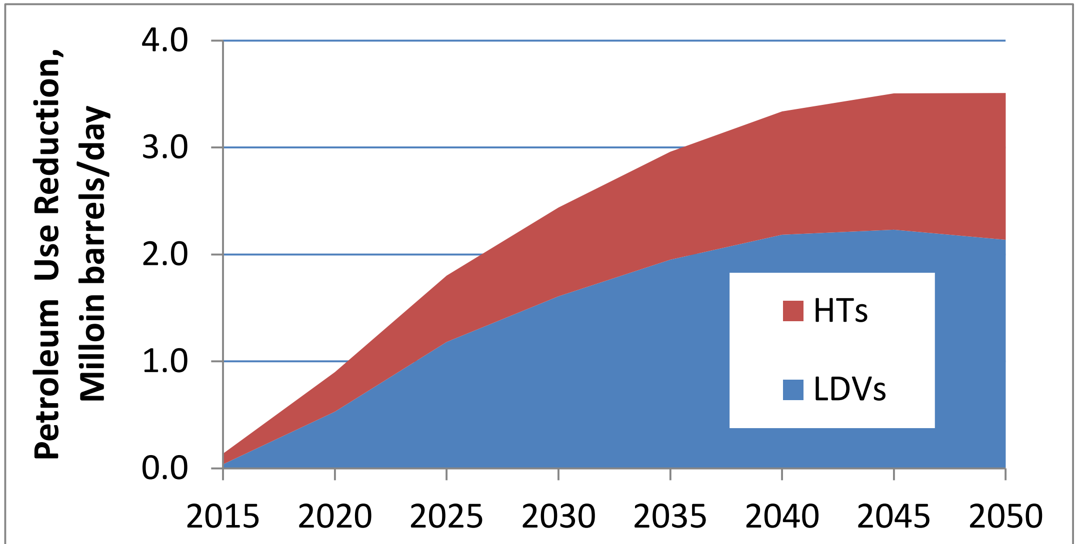


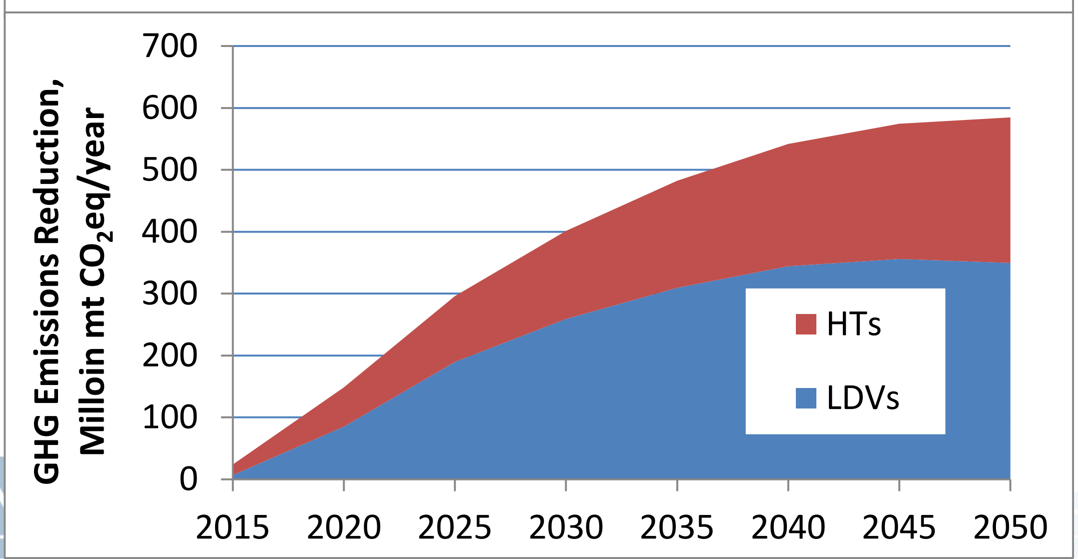
Market Penetration, Class 7&8 Combination



Accomplishment: Projected reductions in petroleum use and GHG emissions

- U.S. on-road fleet



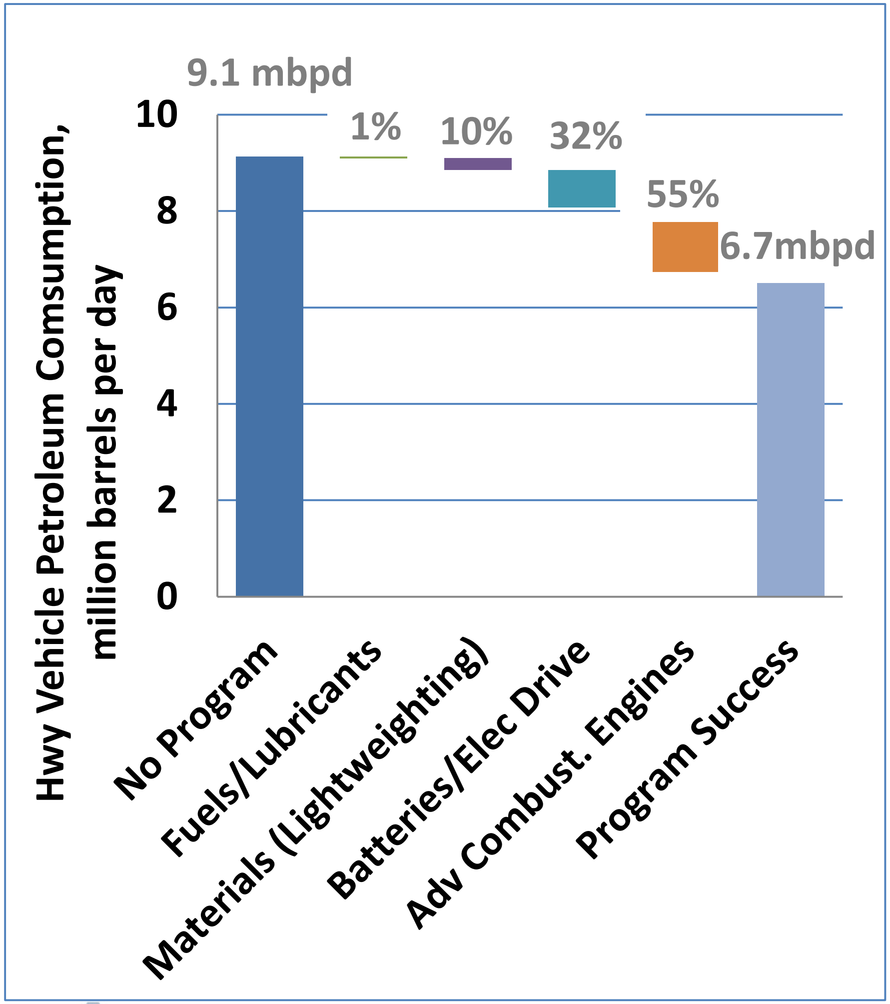


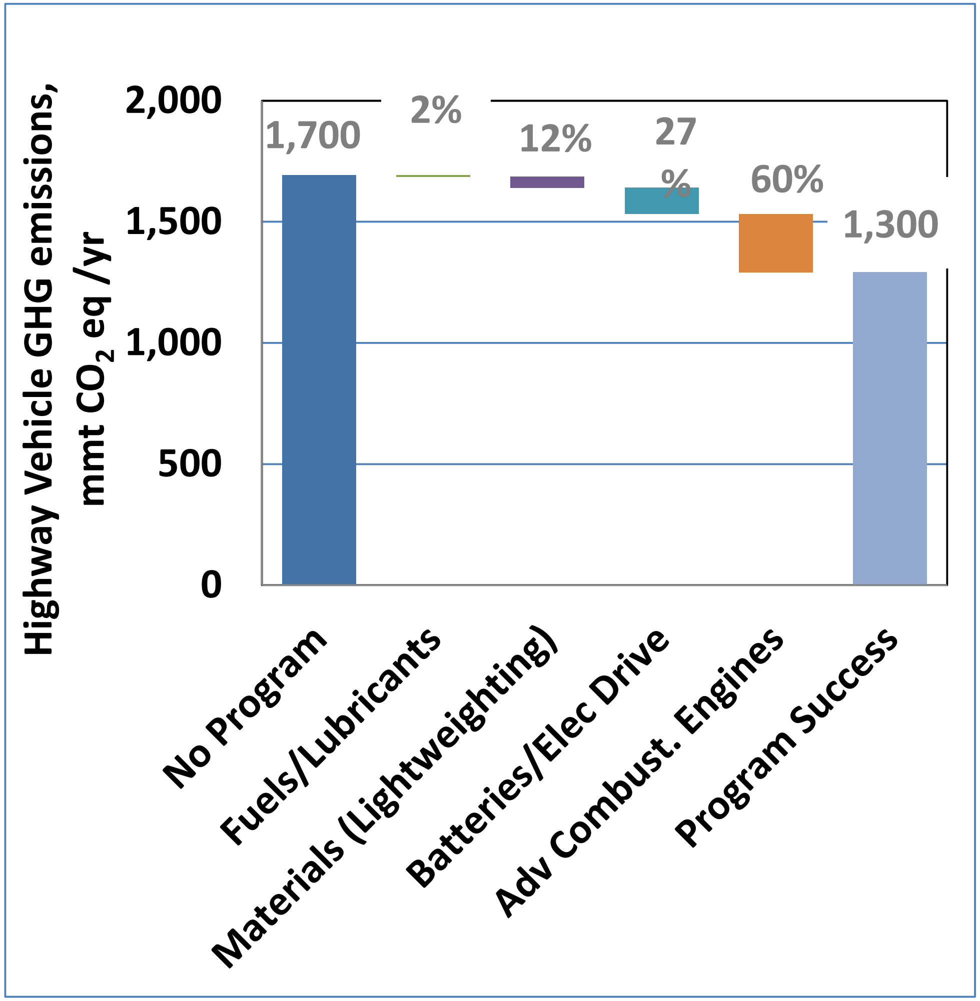
	Annual Oil Use, million bpd	
	No Program, 2050	Program Success, 2050
LDVs	4.3	2.2
HTs	5.2	3.9

	Annual GHGs, million mt CO_2eq/yr	
	No Program, 2050	Program Success, 2050
LDVs	920	570
HTs	660	480

Accomplishment: Projected petroleum savings and GHG reductions *by VTO technology subprogram*

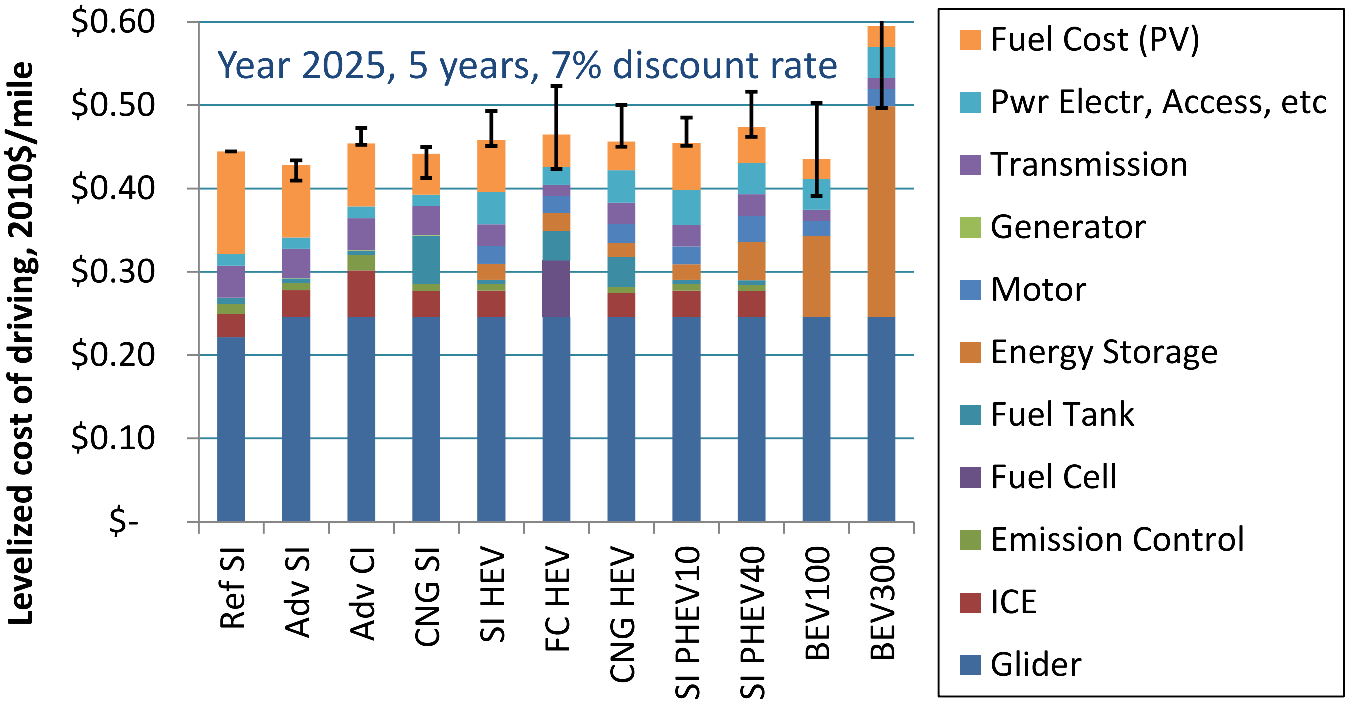
Year 2030





Accomplishment: Levelized cost of PEVs can be competitive with advanced conventional vehicles

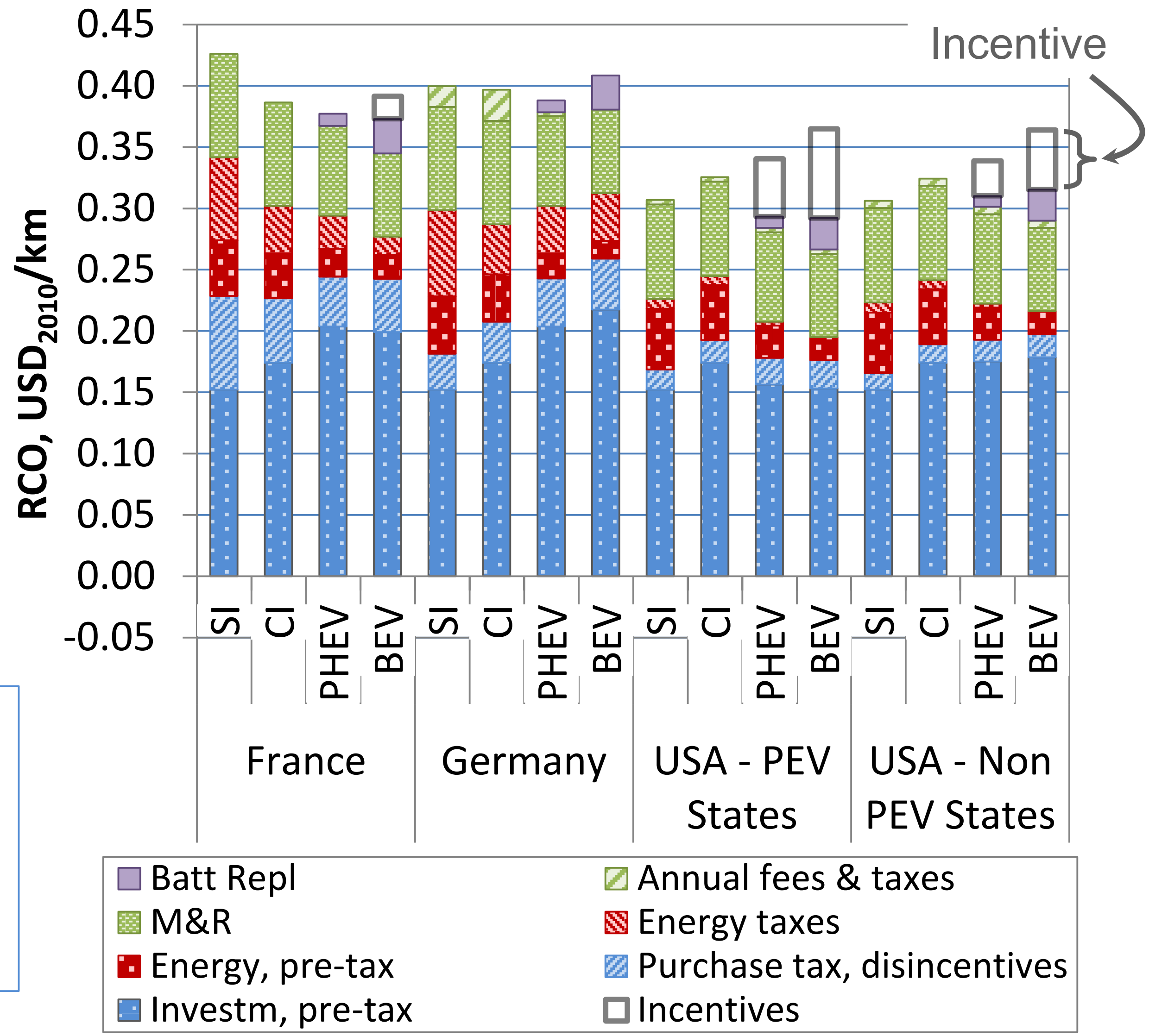
- Levelized cost is the ratio of the present value of the vehicle and fuel to the miles driven in N years



- Error bars show difference between "Program Success" and "No Program" levelized costs

Accomplishment: Comparing cost of ownership in Europe and U.S. shows the importance of taxes and incentives

- RCO: Relevant cost of ownership (more comprehensive than LCD)
- Higher Taxes and fees in France & Germany favor more efficient vehicles
- Bonus/malus in France and purchase incentives in U.S. are important
- Policy drivers can influence RCO and adoption



IEA IA Task 25 on Hybrid and Electric Vehicle Technologies
- France, ifpEN
- Germany, DLR
- Korea, Ulsan Univ.
- U.S., Argonne

Responses to Previous Reviewers' Comments (2013 AMR)

Comment: " ...though the direction of the project supports other projects, the work was done relatively independently."

Response: Increasing interaction with other labs and organizations, especially on vehicle choice models and ownership costs

Comment: "... investigate how the deployment of individual technologies impacts and interacts with the deployment of other technologies. ... how capital and resource constraints of OEMs impact simultaneous deployment of technologies ..."

Response: Project scope in FY14, FY15 does not include supply side constraints such as automaker investment behavior. Informally collaborating with Volpe Lab (USDOT) on supply-side modeling and other projects on market penetration models to address some supply-side limits to adoption rates and CAFE standards. In addition, the on-going BaSce analysis includes deployment of other technologies (fuel cell vehicles, electric charging and hydrogen infrastructure, and alternative fuels) for a transportation-wide assessment.

Comment: " ...more analysis on the transition cost and barrier would make the project more useful."

Response: Vehicle manufacturing costs and costs to consumers are being analyzed, but not all transition costs, but ongoing analysis may be expanded to include low-production volume manufacturing costs (learning-by-doing, economy of scale)

Collaborations

Medium- and heavy duty vehicle modeling, market penetration analysis and benefits estimated are performed by TA Engineering (project #VAN012)

Market penetration analysis was done using the MA^{3}T vehicle choice model developed by Oak Ridge National Lab (project #VAN005) and the TRUCK model (TA Engineering)

Additional market penetration analysis uses other LDV choice models

- LVChoice (TA Engineering, Energetics)
- ADOPT (National Renewable Energy Laboratory)
- Pathways (Sandia National Laboratory)

Other collaborations:

IEA Implementing Agreement Task 25 on Hybrid and Electric Vehicle Technologies; collaborating with the German Aerospace Center, the Fraunhofer Institute, ifp Energies Nouvelles, and Ulsan University on methods and data for estimating vehicle manufacturing and ownership costs and market penetration analysis

Remaining Challenges and Barriers

Make results more robust

- Examine uncertainty in projected market shares. Need to examine the influence of different market penetration levels by advanced vehicles on projected fuel use and GHGs, and socio-behavioral drivers of advanced-technology vehicle adoption
- Assess sensitivity to other variables (fuel prices, vehicle manufacturing energy/GHGs, etc.)
- Improve realism of vehicle attributes: include low-volume manufacturing costs, timing and availability of new models

Assess competitiveness of vehicles with VTO technologies

- More comprehensive assessment of ownership costs, e.g., include all relevant ownership cost, by powertrain type

Expand the scope of benefits analyzed

- Estimate potential reductions in social costs and changes in externalities

Proposed Future Work:

- Remainder of FY15
  - Complete current benefits assessment
  - Examine uncertainty in market shares: Include sales shares projections from several vehicle choice models to assess sensitivity to future sales shares
    - MA^3T, LAVE-Trans (ORNL)
    - LVChoice (Energetics)
    - ADOPT (NREL)
    - Pathways (SNL)
  - Assess sensitivity to other variables: Examine side cases to analyze sensitivity to assumptions (fuel prices, etc.)
  - Assess competitiveness of VTO technologies
    - Identify key factors driving adoption from recent PEV market forecasts for U.S.
    - Assess vehicle choice model assumptions and approaches to represent key factors
    - More comprehensive assessment: Estimate ownership costs by technology, recommend practices to include in benefits assessment
- Future years
  - More comprehensive benefits analysis, broader analysis scope, more realism
  - More uncertainty analysis and side cases to assess robustness

Summary: Successful development and deployment of VTO technologies can reduce petroleum use & GHG emissions

- Relevance: Estimating VTO's potential reductions petroleum use and GHG emissions
- Approach: Scenarios link specific program targets and on-road future benefits
- Accomplishments: Significant benefits from VTO programs
  - Elucidates the contribution of BTO (by technology) to ODE mission
  - Provide quantitative projections to communicate the impacts of VTO technologies

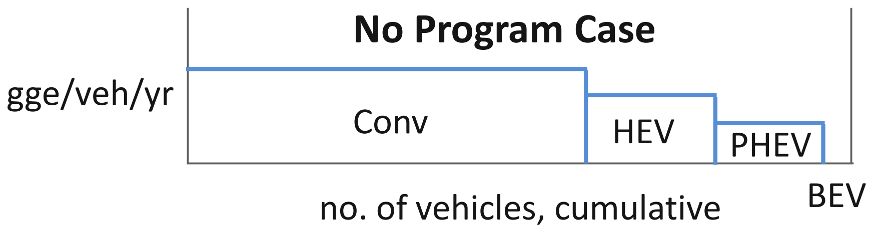
		2030	2050
On-road fuel economy improvement (%)	LDVs	**75%**	**82%**
	HTs	**39%**	**43%**
Oil savings (million bpd)		**2.4**	**3.5**
Annual primary energy savings (quad/yr)		**6.2**	**9.0**
GHG emission reduction (million mt CO_2eq/yr)		**400**	**580**

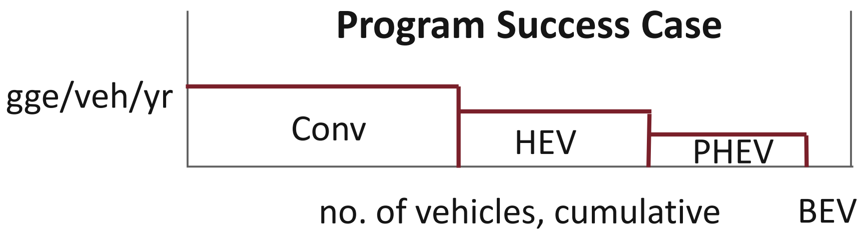
- Proposed future work: Complete ongoing analysis, examine side cases, make analysis more comprehensive

Technical Back-Up Slides

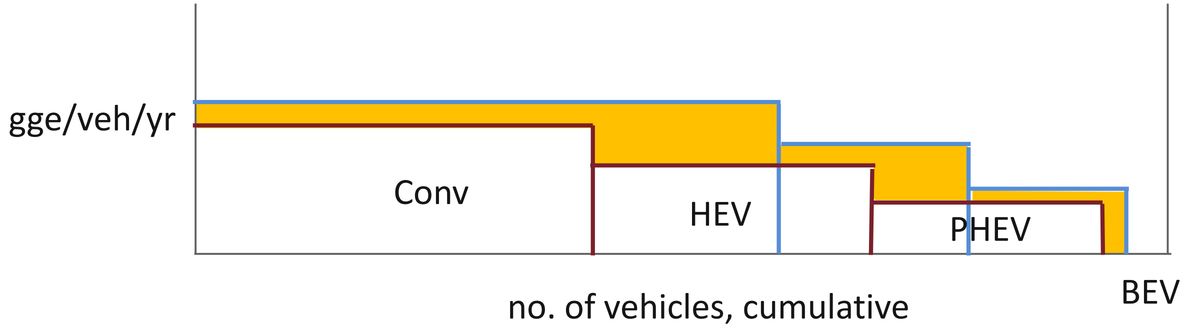
Relating new vehicle fuel consumption to fuel savings by on-road stock, by technology area Approach for LDVs:

- Consider the vehicle stock in a given year



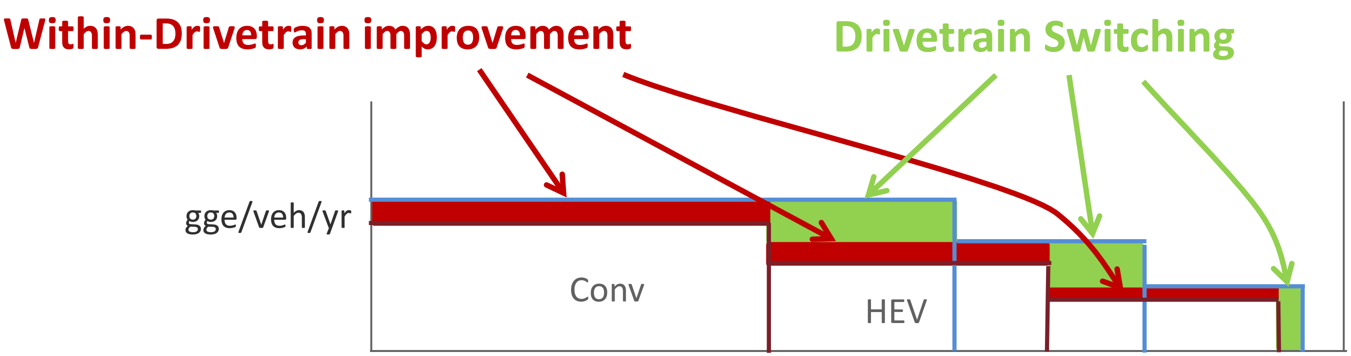


- Plotting the distribution of fuel consumed per vehicle per year for the Program Success and Non Program cases shows the fuel savings (difference shown in yellow)



Relating new vehicle fuel consumption to fuel savings by on-road stock, by technology area Approach for LDVs:

- Lower fuel consumption within each drivetrain: Vehicles of a given drivetrain type are more efficient in the Program Success case
  - This savings is shown in red, below
- Drivetrain switching: Stock shares of vehicles with more efficient drivetrains are higher in the Program Success case
  - This savings is shown in green below



- Fuel savings from drivetrain switching were allocated to Batteries and Electric Drive technologies

Allocating fuel savings from within-drivetrain improvements to technology areas: Approach for LDVs

- For each drivetrain, the reduction in fuel consumption due to each technology area was estimated

$$\frac{FC,\ gge}{mi}$$

$$\frac{\left(\frac{\Delta FC}{FC_0}\right)}{\left(\frac{\Delta frict}{frict_0}\right)} = 0.08$$

$$\frac{\left(\frac{\Delta FC}{FC_0}\right)}{\left(\frac{\Delta RR}{RR_0}\right)} = 0.05$$

$$\frac{\left(\frac{\Delta FC}{FC_0}\right)}{\left(\frac{\Delta mass}{mass_0}\right)} = 0.4 - 0.5$$

$$\frac{\left(\frac{\Delta FC}{aero_0}\right)}{\left(\frac{\Delta RR}{aero_0}\right)} = 0.0155$$

ΔFC → ICE efficiency, or: 70% ICE effic, 30% Hybridzn

Each applied in turn:

- Friction reduction
- Rolling resistance reduction
- Mass reduction
- Aero drag reduction
- ICE efficiency or ICE efficiency + Hybridization