Impact Analysis: VTO Baseline and Scenario (BaSce) Activities

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Argonne National Laboratory

2014 Vehicle Technologies Annual Merit Review

June 18,2013

Project VAN001

Overview

Timeline

- Ongoing Project

Budget

- FY13: $530k
- FY14: $488k

Barriers

- Complexity of relationship between component-level technologies and national-level performance and benefits
- Need for synthesizing VTO modeling, data, and analysis activities
- Lack of understanding of economic effects

Partners

- Interactions / Collaborations
  - TA Engineering (see VAN012)
  - Argonne National Lab (VAN006, VAN008)
  - Oak Ridge National Lab (VAN005)
- Project Lead – Argonne National Lab

Objectives and Relevance

- Objective: Estimate the potential future benefits of the EERE Vehicle Technologies Office (VTO) program at the national fleet 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
  - Advanced combustion engines
  - Fuels and lubricants
  - Materials (Mass reduction)
- Inform VTO Program Managers about impacts of achieving technology program targets
- Provide input to EERE Corporate portfolio benefits analysis

Relevance

- Results from the BaSce analysis have been used in developing technology targets for VTO initiatives:
  - USDRIVE Partnership
  - EV Everywhere Grand Challenge
- Results are also used in several EERE Program Records
- The BaSce analysis process was used for evaluation of the VTO SuperTruck Partnership

Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
Feb 2013	Milestone	Define assumptions and vehicle parameters	Complete
May 2013	Milestone	Estimate fuel consumption and costs for all vehicles[1, 2]	Complete
Jun 2013	Milestone	Establish baseline case	Complete
Jul 2013	Milestone	Estimate fleet-wide benefits for light-duty vehicles and heavy trucks[2]	Complete
Added, Nov 2013	Milestone	Allocate benefits by technology area	Complete
Aug 2013	Milestone	Document estimated benefits	Complete

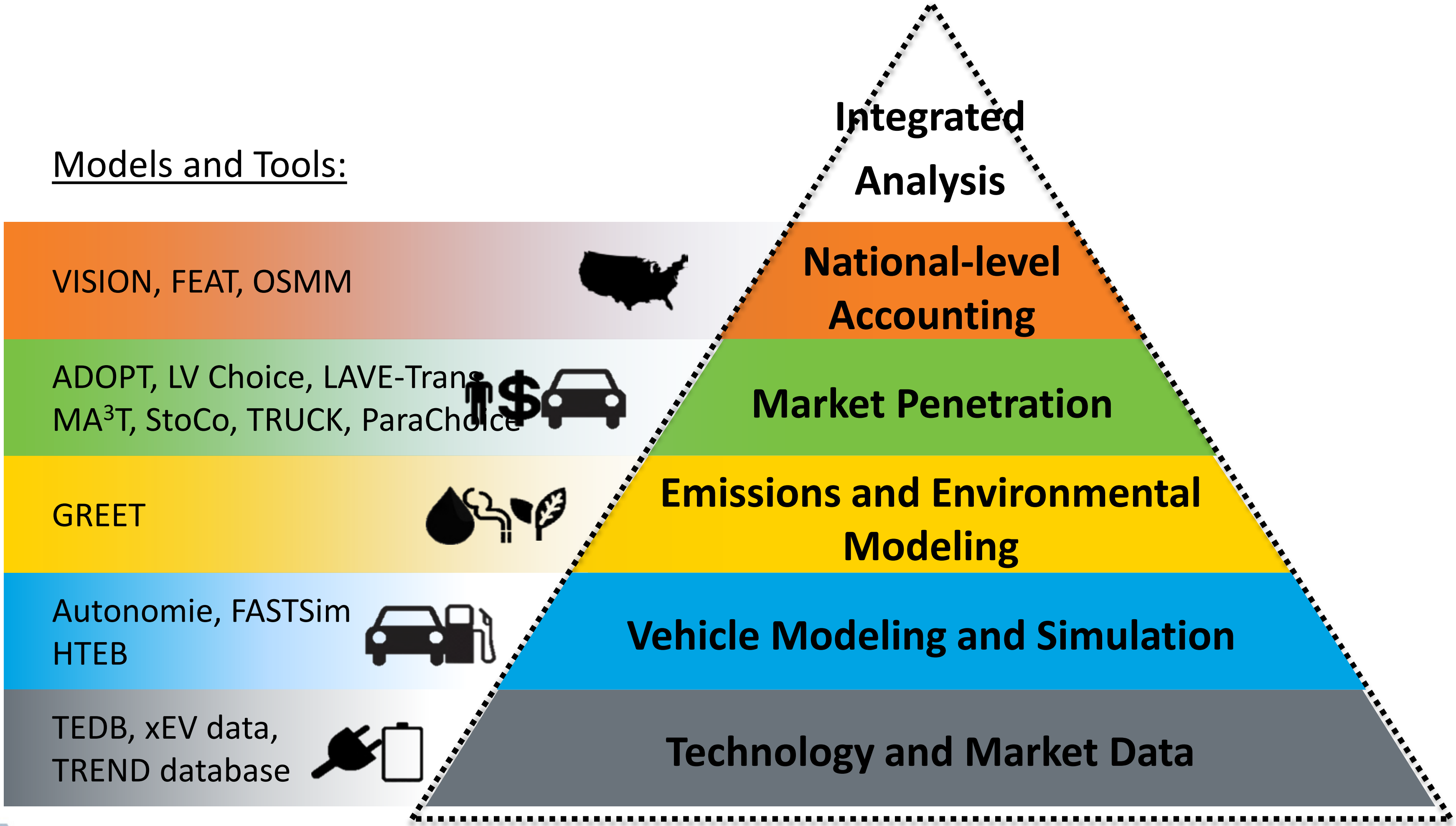
[1]Light-duty vehicle simulations performed by ANL Autonomie Team (see #VAN008)
[2]Htrucks analyzed by TA Engineering using TRUCK model suite (see #VAN012)

Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
Oct 2014	Milestone	Define assumptions and vehicle parameters	Not started
Nov 2014	Milestone	Establish baseline case	Not started
Dec 2014	Milestone	Complete initial vehicle modeling	Not started
Jan 2014	Milestone	Complete initial market penetration analysis	Not started
Feb 2014	Milestone	Revise vehicle and market penetration analyses	Not started
Feb 2014	Milestone	Complete fleet-level analysis and estimate benefits	Not started
Mar 2015	Milestone	Write reports	Not started
Apr 2015	Milestone	Issue final reports	Not started

BaSce is the “capstone” of VTO analysis activities

- Integrates models. Data and analysis from the VTO Analysis portfolio to develop scenarios of VTO technologies for assessing potential benefits



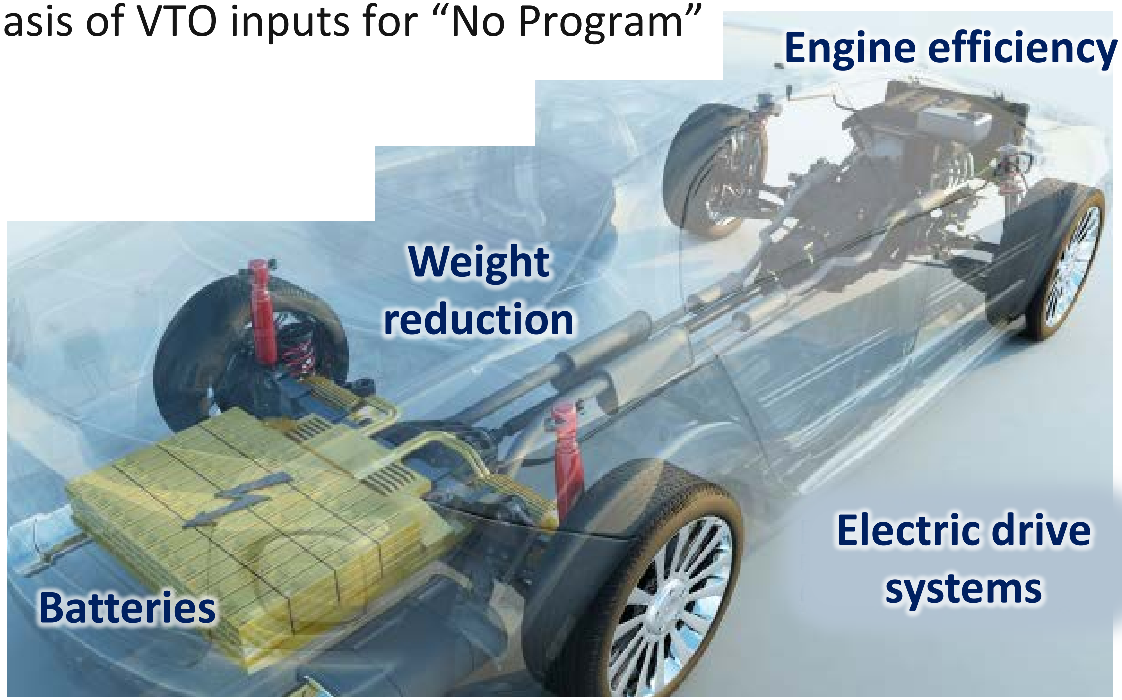
Approach: Compare two cases, with and without successful deployment of VTO Technologies

- 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 programs have component-level cost and performance targets for:

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

For light-duty and heavy-duty vehicles



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^3T; HDVs: TRUCK model)
- **Stock model** — Calculate fleet stock, and 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^3T: Market Acceptance of Advanced Automotive Technologies (ORNL)
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):

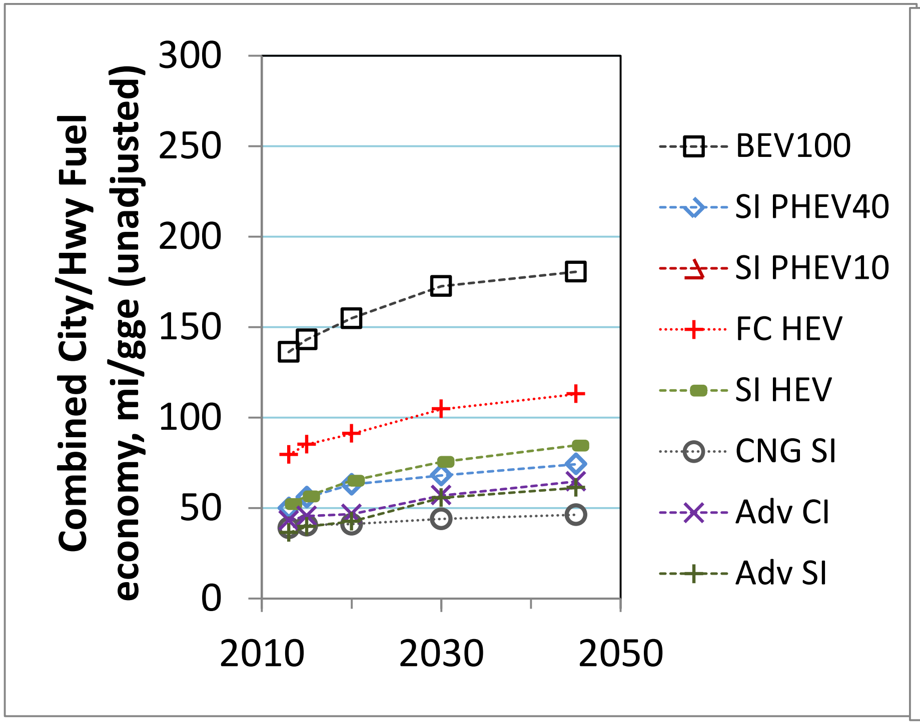
- Best-In-Class CI Conv
- Advanced CI
- Parallel HEV CI

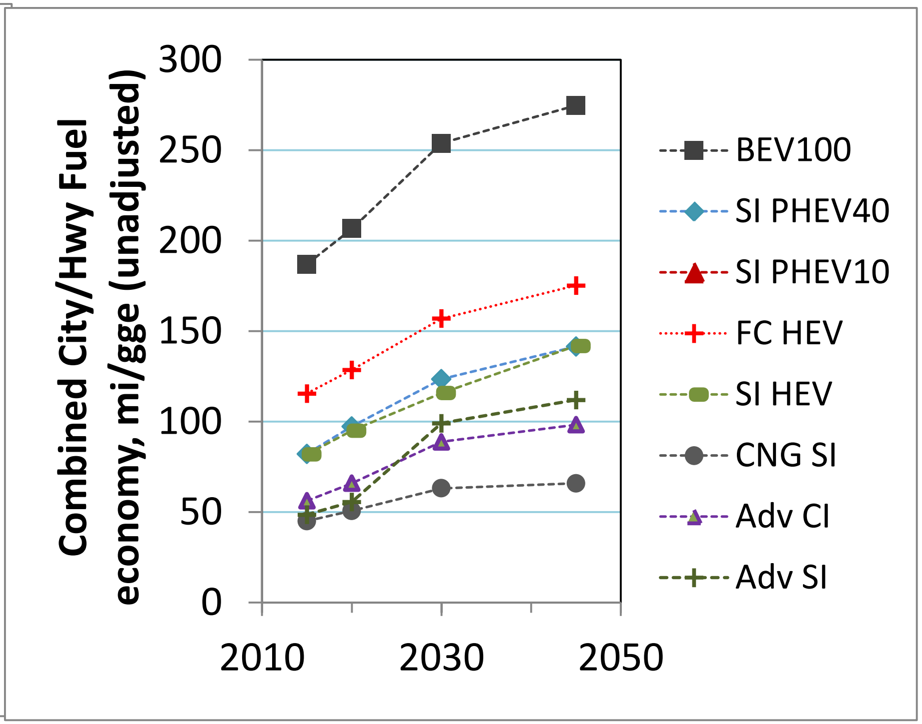
Assumptions

- 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

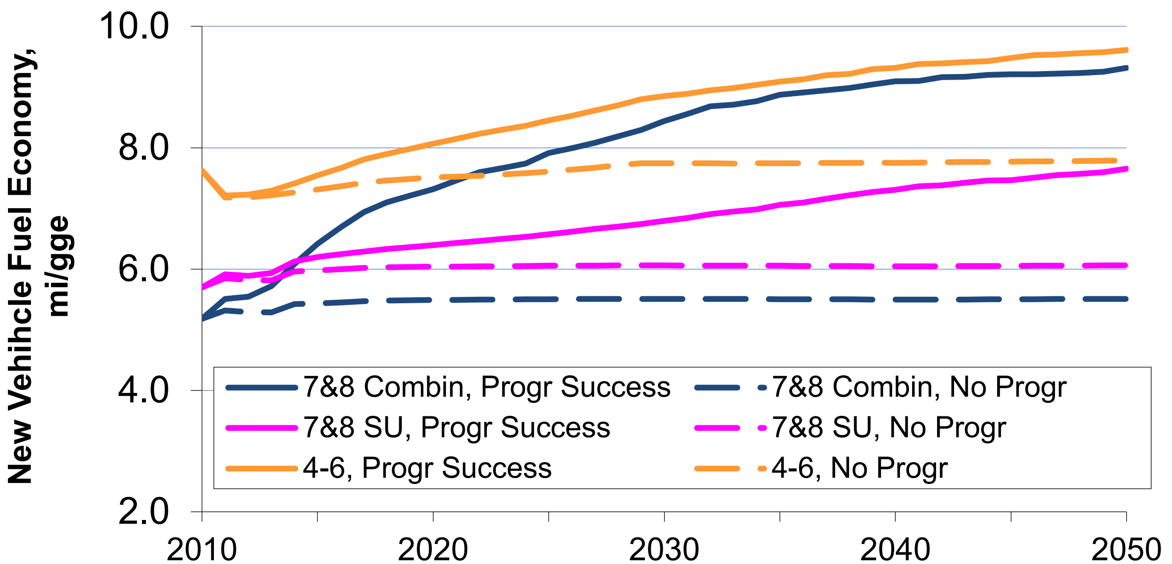
- Vehicles simulated in UDDS and HWFET drive cycles
- Combined city/highway (55/45), unadjusted values shown



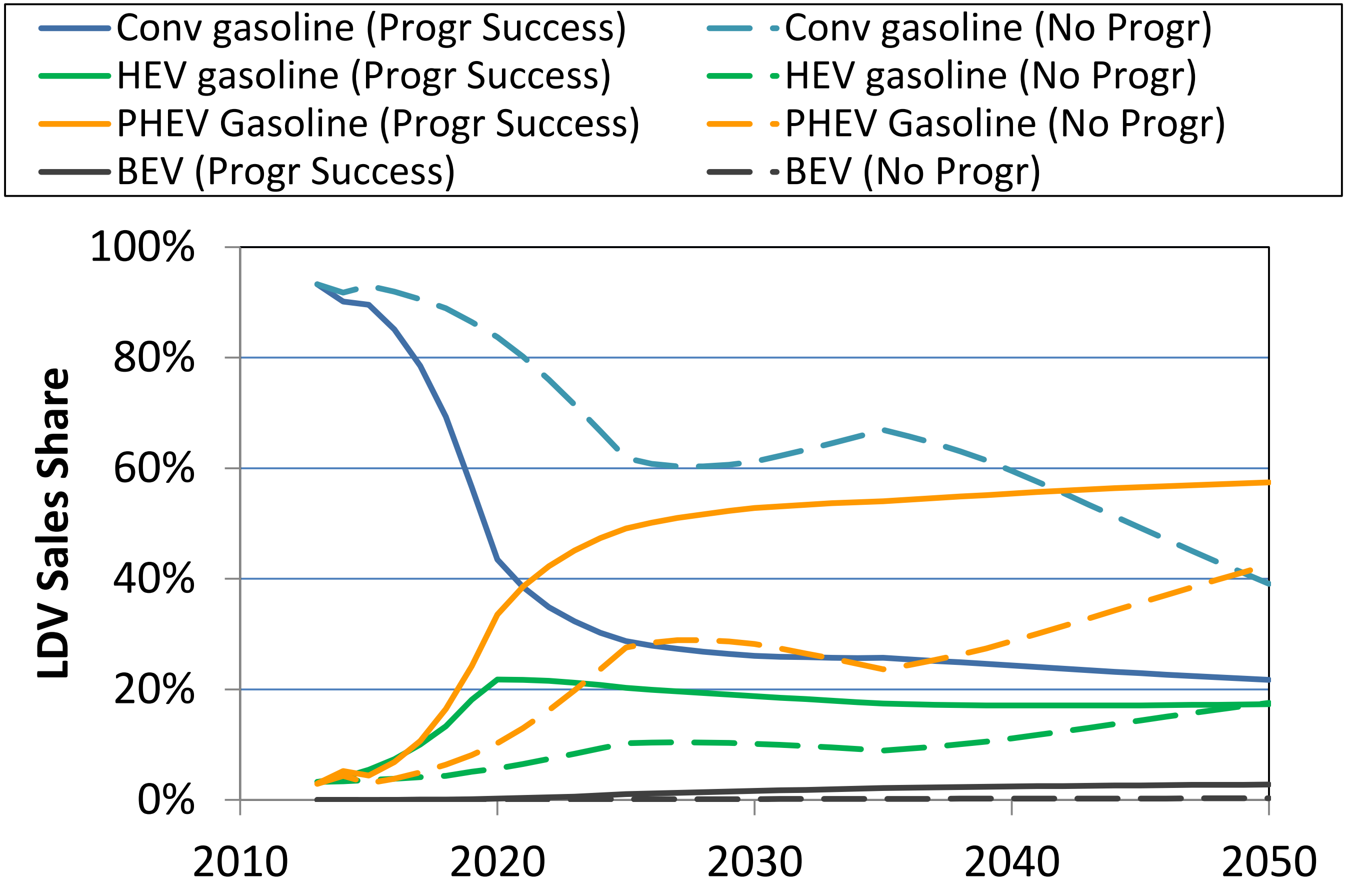


Heavy- and medium-duty fuel economies are higher in the Program Success case

- 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)



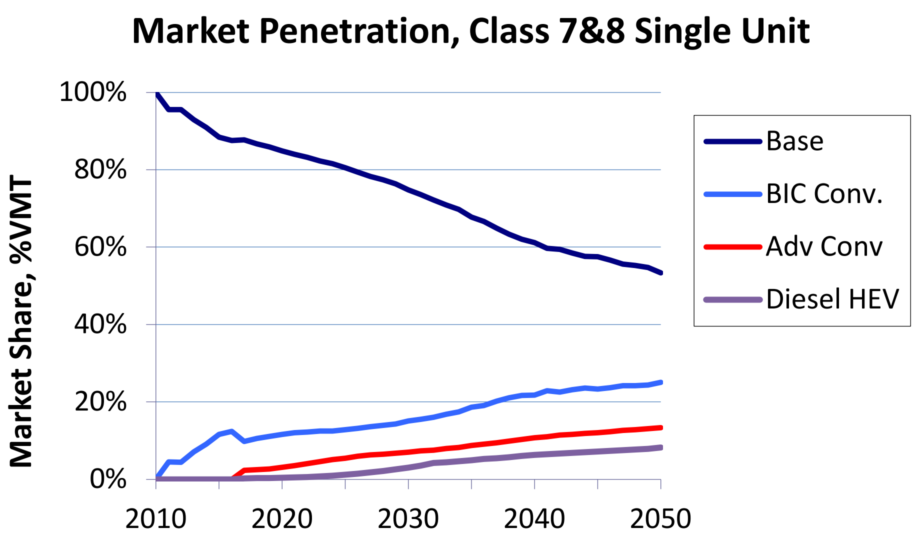
Projected LDV market shares by drivetrain type

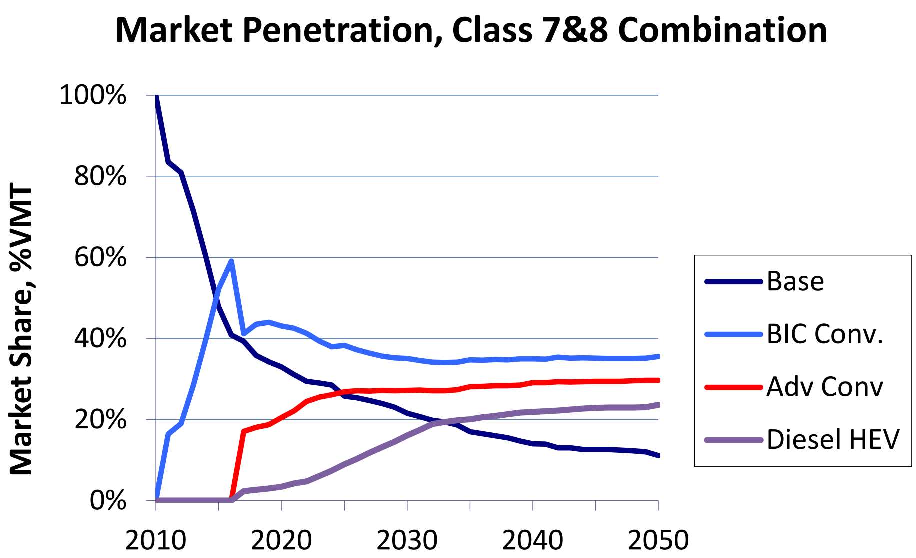


- Much more rapid market penetration by HEVs and PHEVs in the "Program Success" case
- Little penetration of BEVs or FCVs in these cases (little public charging or hydrogen infrastructure assumed) make/model availability assumed

Projected market penetration, Class 7&8 trucks

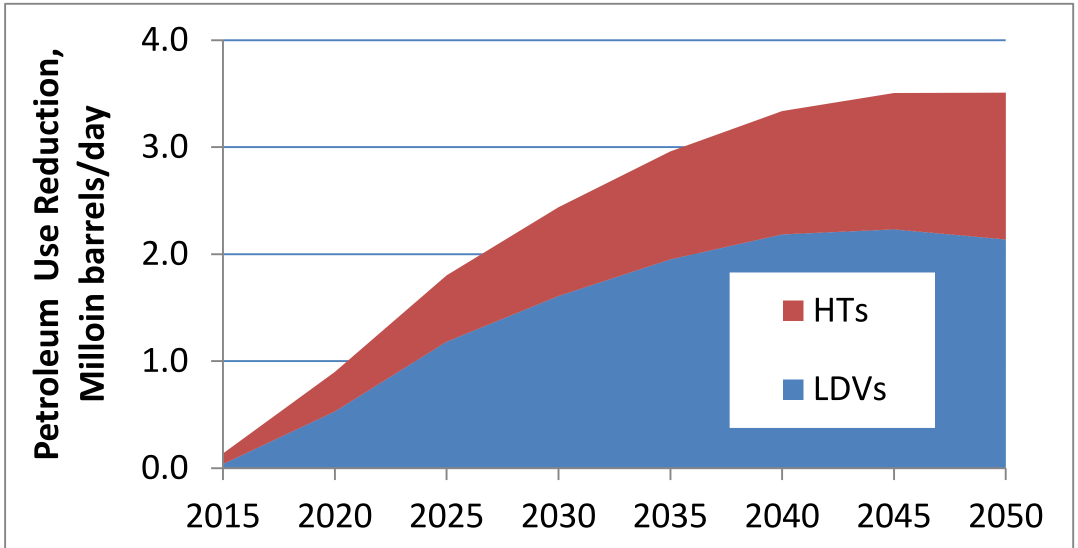
- Much more rapid market penetration by advanced technologies in Class 7&8 combination units, due to higher annual VMT and more rapid payback

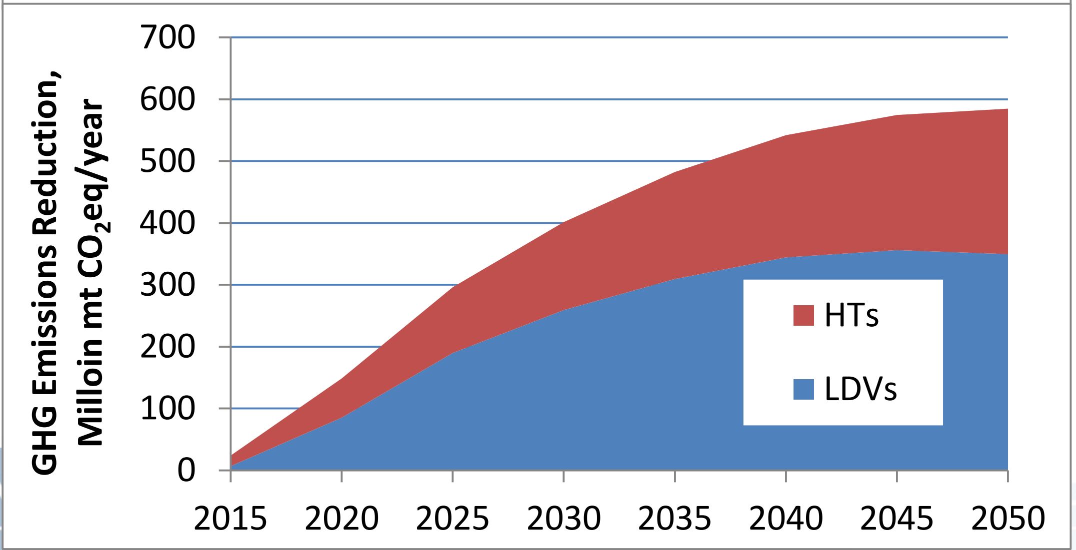




Projected reductions in petroleum use and GHG emissions

- U.S. on-road fleet



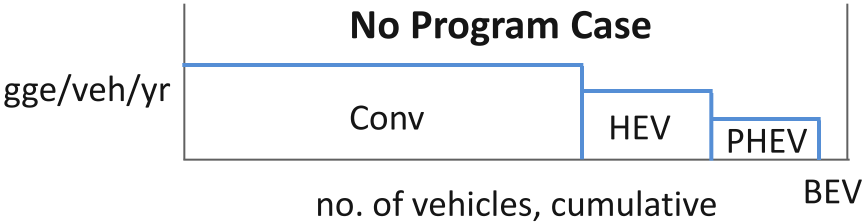


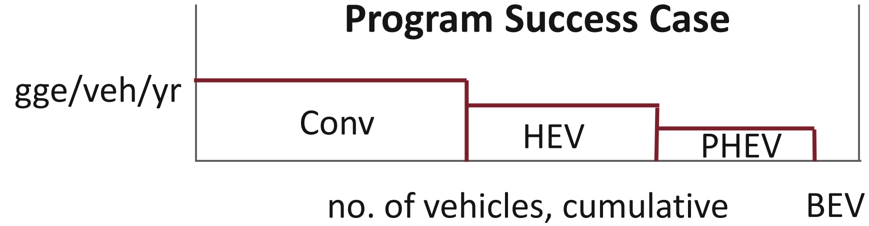
	Annual Oil Use, million bpd	
	No Program, 2050	Target, 2050
LDVs	4.3	2.2
HTs	5.2	3.9

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

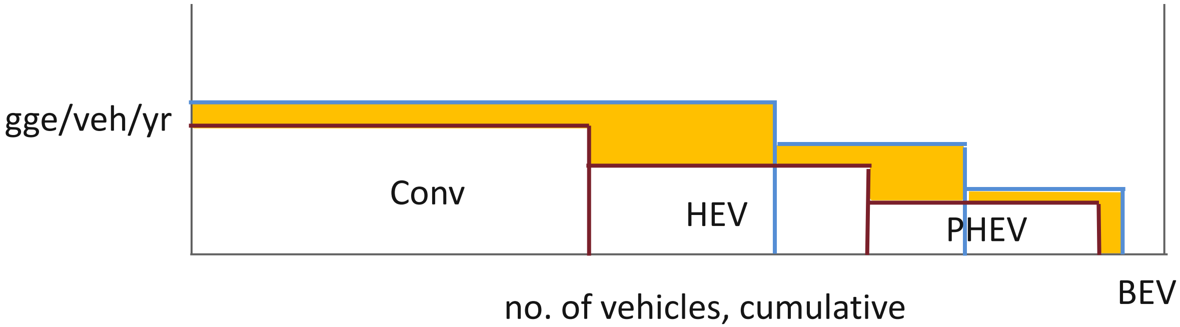
Relating new vehicle fuel consumption to fuel savings by on-road stock, by technology area

- Consider the vehicle stock in a given year (ignoring variability in fuel consumption with age, VMT/yr)



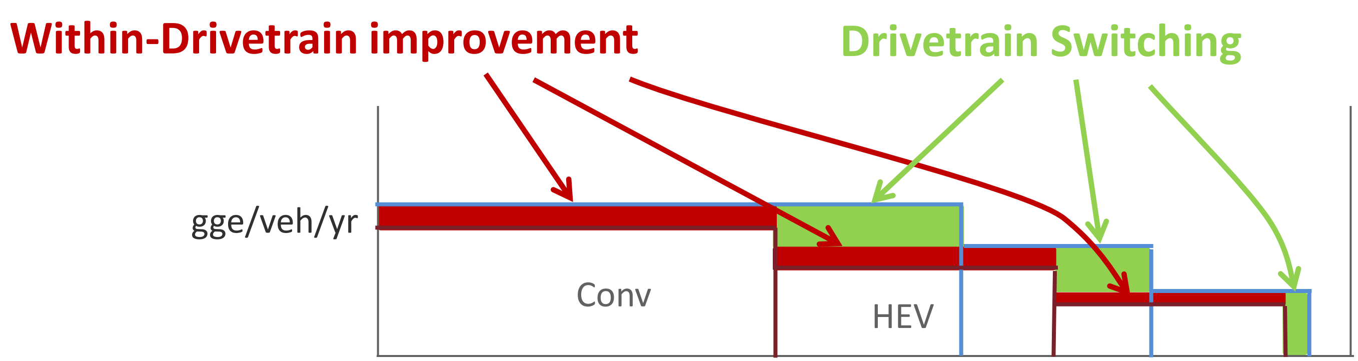


- Plotting the distribution of fuel consumed per vehicle per year for the Target and Non Program cases shows the fuel savings (difference shown in yellow)



Relating new vehicle fuel consumption to fuel savings by on-road stock, by technology area

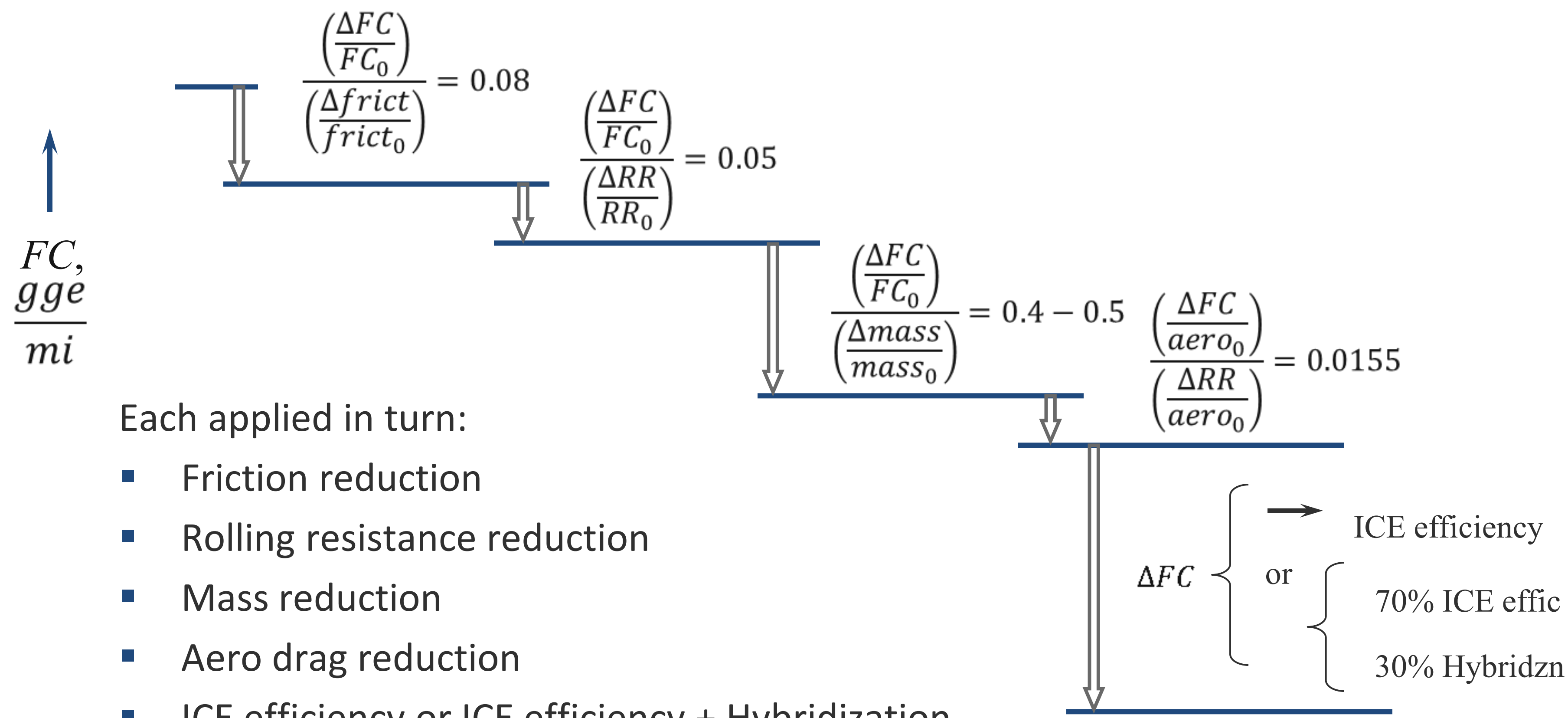
- Lower fuel consumption within each drivetrain: Vehicles of a given drivetrain type are more efficient in the Target case
  - This savings is shown in pink, below
- Drivetrain switching: Stock shares of vehicles with more efficient drivetrains are higher in the Target case
  - This savings is shown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

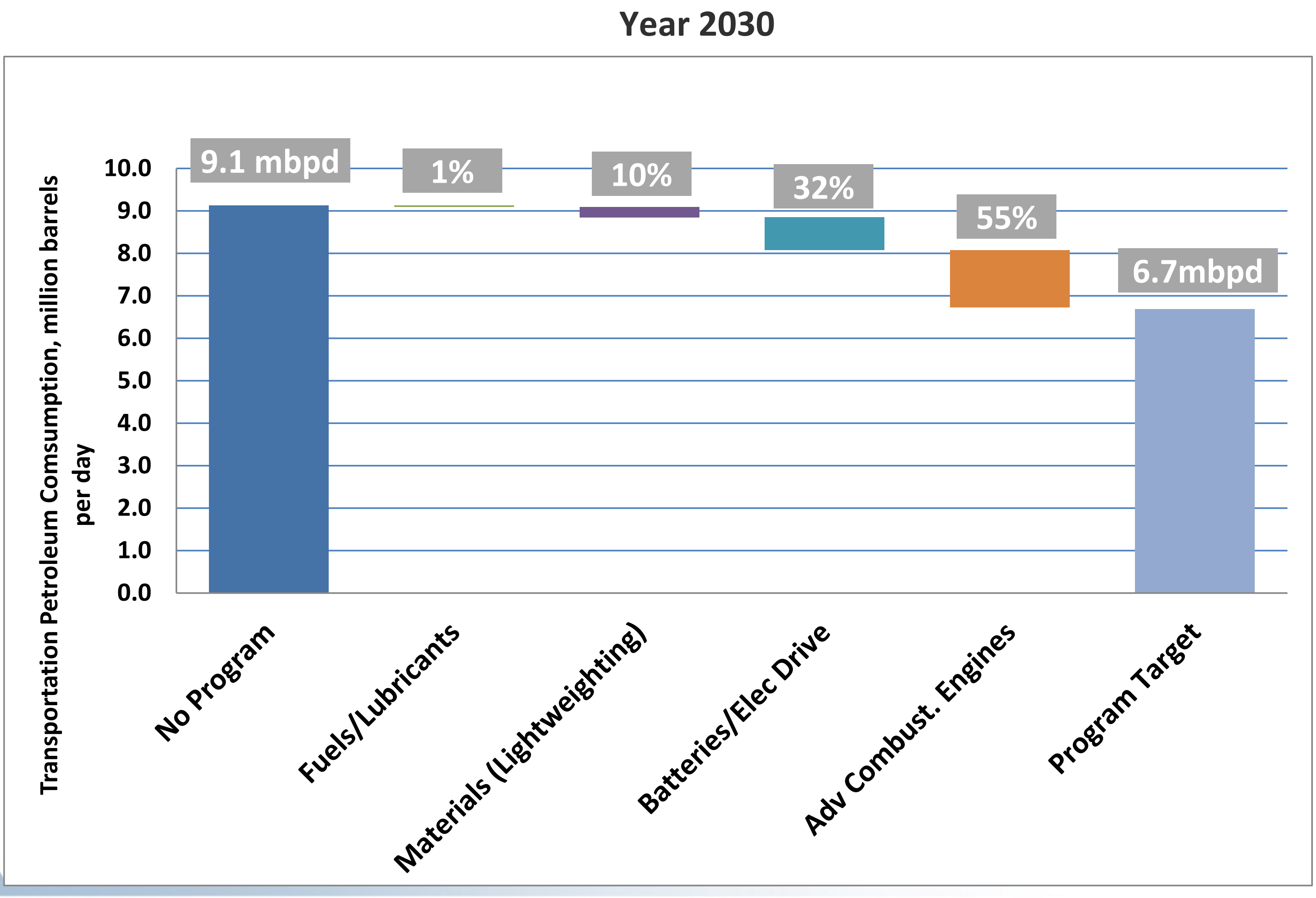
- For each drivetrain, the reduction in fuel consumption due to each technology area was estimated



Each applied in turn:

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

Projected petroleum savings by VTO technology subprogram



Levelized cost of driving (LCD) includes vehicle and fuel purchase

- Vehicle purchase price estimated from component manufacturing costs and retail price equivalent (RPE) factor
- Fuel includes liquid, gaseous fuels and electricity
- Other costs (maintenance, depreciation, insurance, fees, etc.) are assumed to be similar across vehicle types
- Data needed to include these other costs
- Levelized cost is the ratio of the present value of the vehicle and fuel to the miles driven in N years

$$LC = \frac{P_V + PC(C_{Fi})}{\sum_i^N VMT_i}$$

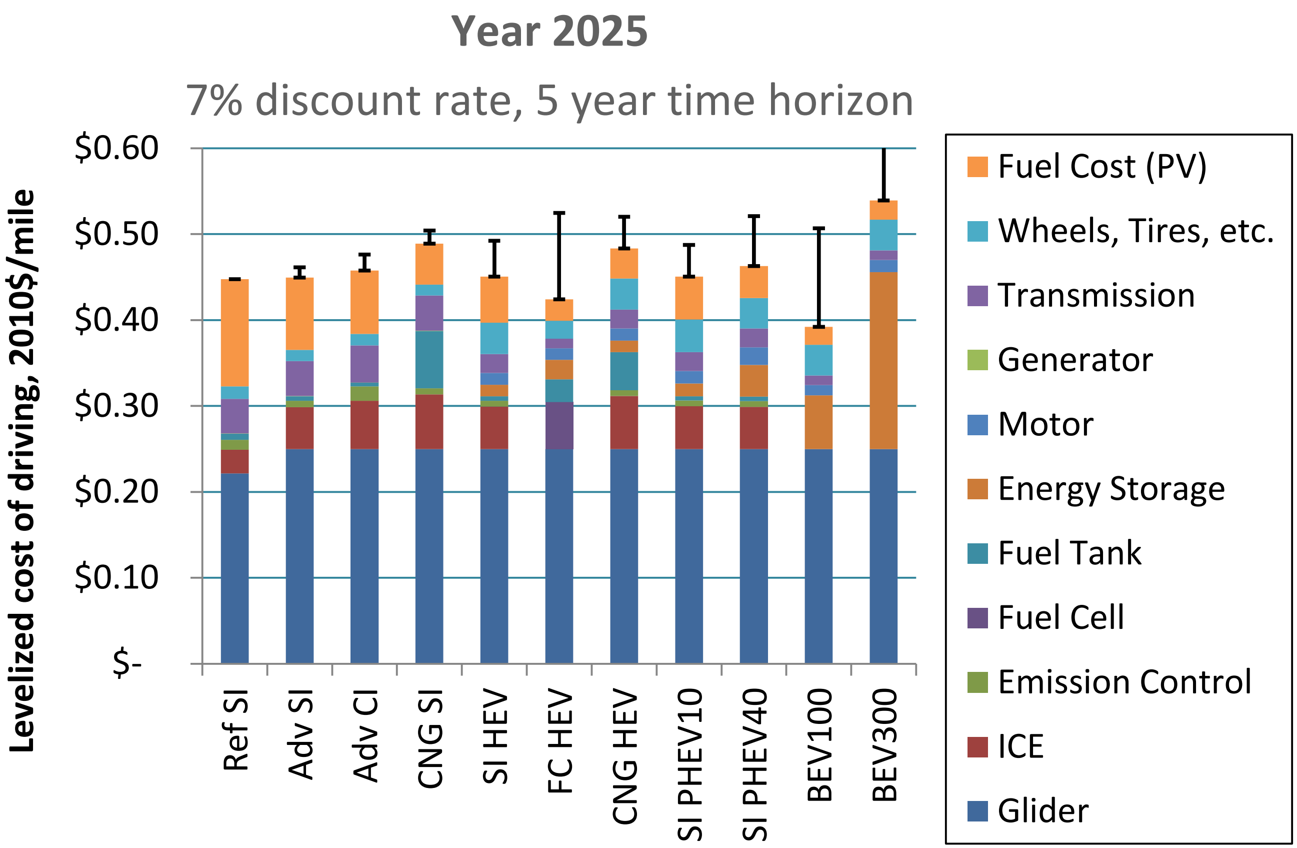
P_V = purchase price of vehicle

C_{Fi} = cost of fuel in year i

VMT_i = vehicle miles traveled in year i

N = Time horizon, years

Levelized cost estimates show that PEVs can be cost-competitive with advanced conventional vehicles



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

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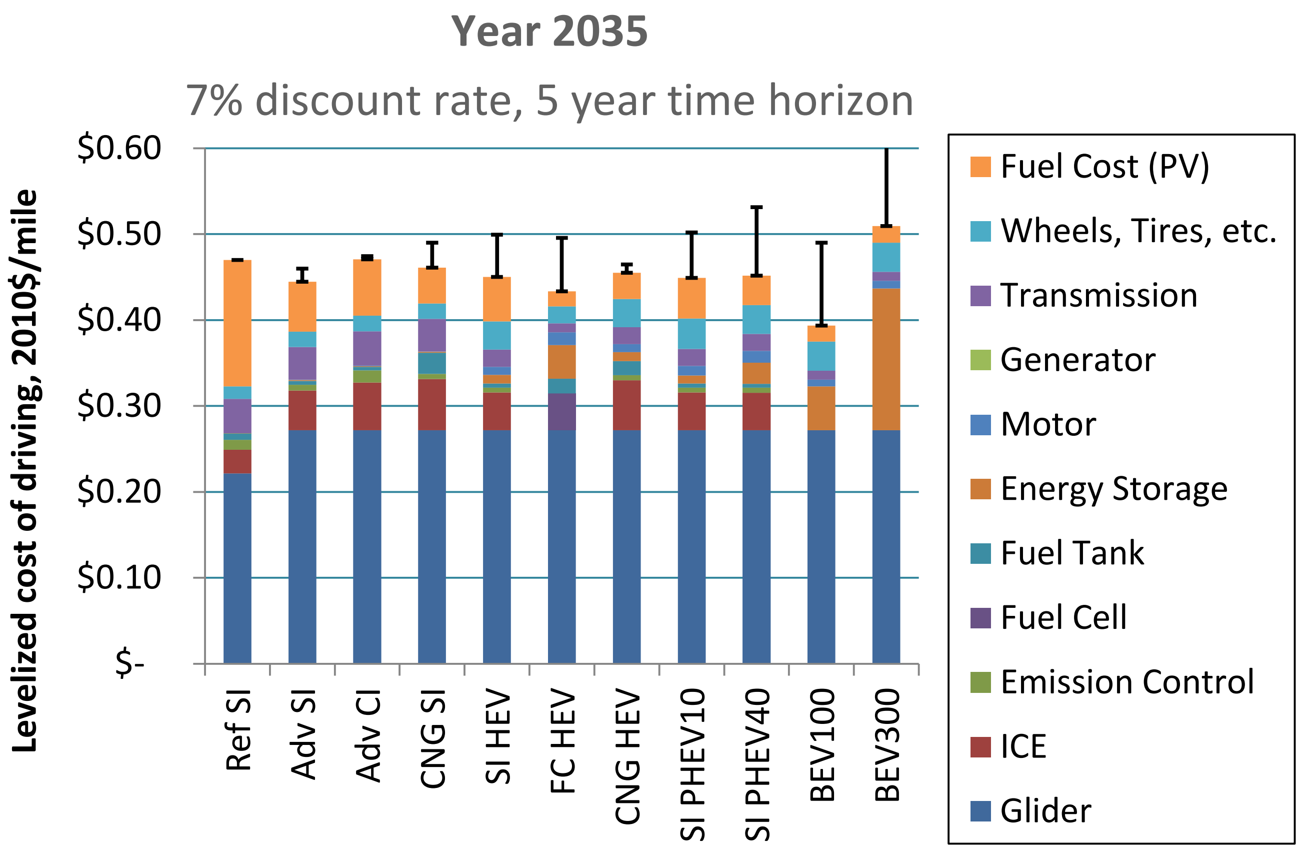

- Error bars show difference between “Program Success” and “No Program” levelized costs

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

Scenarios analyzed provide a link between specific program targets and future benefits

- Benefits from hybridization are significant for LD HEVs and PHEVs
- Benefits from increased engine and drivetrain efficiency are large for heavy and medium duty trucks

		2030	2050
On-road fuel economy improvement (%)	LDVs	**75%**	**82%**
	HTs	**39%**	**43%**
Annual 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**

Stephens, T.S.; Birky, A.K.; Ward, J (2014) Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2015," Argonne National Laboratory report ANL/ESD-14/3.

Collaborations

Light-duty vehicle simulations are performed by Argonne Autonomie team (project #VAN008)

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

Market penetration analysis is done using the MA^3T vehicle choice model developed by Oak Ridge National Lab (project #VAN005

Other collaborations:

Collaborating with the German Aerospace Center and the Fraunhofer Institute on methods and data for estimating vehicle manufacturing and ownership costs and market penetration analysis

Collaborating with Oak Ridge National laboratory, National Renewable Energy Laboratory, Sandia National Laboratory and TA Engineering on developing and comparing vehicle choice models for market penetration of light duty vehicles

Proposed future work:

- Collect data on automaker capital investments in advanced-technology vehicle production
- Include sales shares projections from several vehicle choice models
- Include energy and GHG emissions from vehicle lifecycle
- More comprehensive levelized cost estimation, e.g., include resale, maintenance, etc.
- Include constraints on market penetration rate based on historical rates, supply constraints

Publications and Presentations

Publications and Presentations on work presented here:

Stephens, T.S.; Birky, A.K.; Ward, J (2014) *Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2015*, Argonne National Laboratory report ANL/ESD-14/3.

Stephens, T.S., Birky, A.K. and Ward, J. (2013) *Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2014*, ANL-13/24.

Stephens, T., A. Rousseau and J. Ward, (2014) *Advanced Vehicle Price and Market Projections*, SAE 2014 Hybrid and Electric Vehicle Technologies Symposium, La Jolla, CA, Feb 11–13,

Publications and Presentations on other work under this project

Santini, D; D. Poyer, (2013) *Gasoline Prices, Vehicle Spending and National Employment: Vector Error Correction Estimates Implying a Structurally Adapting, Integrated System, 1949-2011* at the 32nd U.S. and International Associations for Energy Economics' North American Conference, Anchorage, AK, July 28–31.