

Status of EPA's Technology Assessment for the Midterm Evaluation

2022-2025 GHG Emissions Standards

June 23, 2014



**Office of Transportation and Air Quality
Office of Air and Radiation
U.S. Environmental Protection Agency**



- 1. Introduction**
- 2. Technology Effectiveness & Tool Development**
 - a) Vehicle, Engine, Transmission Benchmarking
 - b) Models and Validation
- 3. Technology Cost Updates**
- 4. Mass Reduction Studies**
- 5. Consumer Issues**
- 6. Wrap-up**

Introduction



- EPA would like to continue to support the NAS Committee's Phase 2 Report on Fuel Economy of Light-duty Vehicles
- We will consider the report's findings as part of the midterm evaluation of Model Year (MY) 2022-2025 standards.
- At the first NAS Committee meeting in Spring 2012, EPA presented the wide range of technical work completed during 2008-2012 timeframe to inform the MY 2012-2016 and MY 2017-2025 standards rulemakings

What have we been doing since 2012?



Learning from others

- Reviewed hundreds of new papers and reports in the literature
- Attended nearly two dozen technical conferences (SAE, battery developments, mass reduction, powertrain advancements, etc)
- Met thus far with:
 - more than 20 suppliers (transmissions, materials, active grill shutters, electrical components, turbochargers, sensors, etc.)
 - majority of OEMs (in some cases, multiple times)
 - other stakeholders (e.g., Environmental NGOs and consumer groups)
- Will continue active stakeholder outreach throughout process

Initiating new technical work

- Published several peer reviewed papers in 2013-2014 (see Appendix)
- EPA will continue this work for 2015 and beyond to inform the midterm evaluation

Today, EPA will present high level overview of work initiated in 2012-2014

Midterm Evaluation

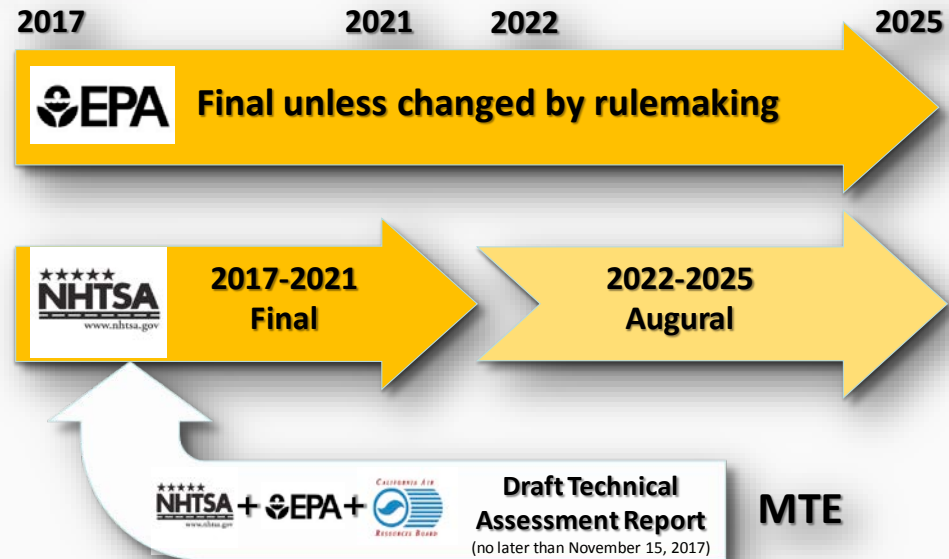


- ✓ EPA, NHTSA, and California ARB have committed to collaborate on a midterm evaluation of the standards for model years 2022-2025
 - Draft *Technical Assessment Report* for public comment by Nov 15, 2017
 - EPA final determination by Apr 2018

- ✓ The midterm evaluation could result in a determination that the 2022-2025 standards should remain unchanged, or be changed to a stringency level either higher or lower

- ✓ Agencies will review a wide range of factors such as:

- Powertrain improvements, weight reduction and safety impacts, market penetration and consumer acceptance of fuel efficient technologies, fuel prices, infrastructure, consumer payback periods, car/truck fleet mix changes, etc.



U.S.-Canada Collaborative Efforts: Environment Canada, Environmental Protection Agency, Transport Canada



- ✓ **EPA is also collaborating with Environment Canada and Transport Canada**
 - Through mechanisms, such as the *Canada-U.S. Air Quality Agreement* and the *Regulatory Cooperation Council*, Environment Canada (Energy & Transportation Directorate), Transport Canada (ecoTECHNOLOGY for Vehicles Program) and the EPA (Office of Transportation and Air Quality) have on-going trilateral meetings to identify opportunities for technical collaboration.
- ✓ **Part of Canada's \$870M Clean Air Agenda announced in 2011, the ecoTECHNOLOGY for Vehicles (eTV) Program is a \$37.9M Government of Canada program that tests and evaluates the safety and environmental performance of advanced light-duty vehicle (LDV) and heavy-duty vehicle (HDV) technologies.**
- ✓ **Based on these discussions, a number of collaborative testing activities are currently underway that focus on several areas, including vehicle aerodynamics, light-weighting and vehicle modeling, among others.**





1. Status of LD GHG Rule & MTE Activities

2. Technology Effectiveness & Tool Development

- a) Vehicle, Engine, Transmission Benchmarking
- b) Models and Validation

3. Technology Cost Studies

4. Mass Reduction Studies

5. Economic Factors

6. Wrap-up

EPA's Advanced Technology Testing



EPA's National Vehicle and Fuel Emissions Laboratory – Part of EPA's Office of Transportation and Air Quality in Ann Arbor, MI

NVFEL is a state of the art test facility that provides a wide array of dynamometer and analytical testing and engineering services for EPA's motor vehicle, heavy-duty engine, and nonroad engine programs which:

- Certify that vehicles and engines meet federal emissions and fuel economy standards
- Test in-use vehicles and engines to assure continued compliance and process required enforcement actions
- Analyze fuels, fuel additives, and exhaust compounds
- Develop future emission and fuel economy regulations
- Develop laboratory test procedures
- **Research future advanced engine and drivetrain technologies (involving 20+ engineers – modeling, advanced technology testing and demonstrations)**

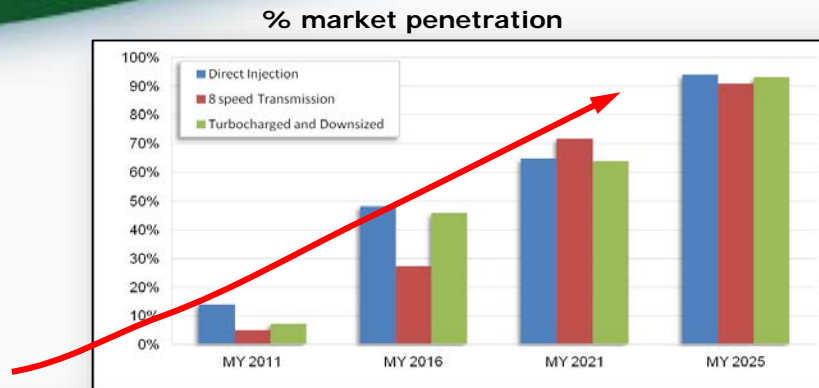
**National Center for
Advanced Technology (NCAT)**

NVFEL is proud to be an ISO certified and ISO accredited lab -- ISO 14001:2004 and ISO 17025:2005.

Expected Low-GHG/Fuel Efficient Technologies



- ✓ In the rulemaking,
 - Vehicle simulations were a key element in assessing feasibility
 - Standards assume increasing use of advanced technology



Engines

- ✓ Gasoline Direct Injection (GDI)
- ✓ Turbocharging & downsizing
- ✓ High CR Naturally Aspirated
- ✓ Diesels
- ✓ Start-stop systems

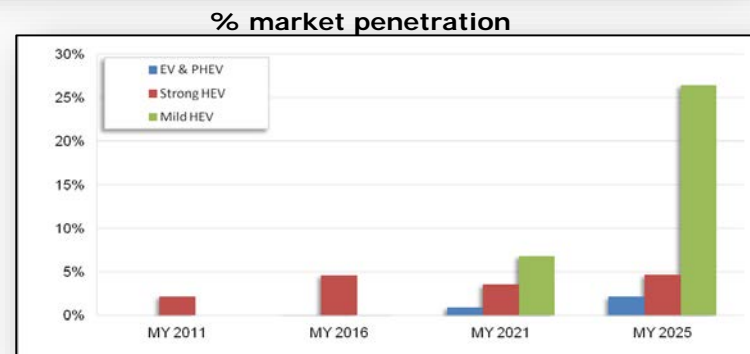
Chassis

- ✓ Advanced transmissions
- ✓ Mass reduction
- ✓ Improved aerodynamics
- ✓ Low RR tires
- ✓ Efficient accessories
- ✓ Improved A/C

Hybrids

- ✓ Mild hybrids
- ✓ Strong hybrids
- ✓ PHEV/EREVs
- ✓ EVs

- ✓ Manufacturers are already implementing newer technology.
- ✓ As technology is implemented, testing helps us gain a better understanding of how technologies are implemented and provide for improved calibration of vehicle simulation tools.



Innovations Coming Fast

We are already seeing innovations in the marketplace beyond what EPA considered in setting the standards ... just a few examples:

✓ **Powertrain**

- Manufacturers are developing new technologies we didn't even consider in the rule, such as Mazda's **ultra-capacitor based start-stop system** and Volvo's **flywheel hybrid system**
- Manufacturers are marketing technologies in greater volumes than we projected, such as **increasing popularity of diesels** in the Ram 1500 pickup, and coming in Nissan Titan and BMW sedan
- Manufacturers are applying technology differently than we expected, such as Volkswagen's application of **cylinder deactivation on a 4-cylinder engine**.

✓ **Transmissions**

- **8-speed transmissions entering market sooner** that we projected
- **9-speeds have been introduced** from Chrysler and Daimler
- **10-speed developments** announced by GM/Ford jointly, VW, Hyundai, Kia
- New generation **continuously variable transmissions** offered by Nissan, Honda, Subaru, others

Innovations Coming Fast

And innovations are not just limited to engines and transmissions:

✓ **Active Aerodynamics**

- **Active ride height** on Jeep Grand Cherokee and Dodge Ram pickup
- **Active grill shutters** on Chevy Cruze Eco and Ford Focus

✓ **Light-weighting**

- **Design optimization for geometry and material** (Acura MDX, Cadillac ATS, many more)
- **Widespread adoption** of aluminum hoods and fenders
- **Aluminum body structures** in mass market vehicles (F150)

Benchmarking Key Vehicle Powertrain Technology



We are benchmarking vehicles with several important technologies:

Engines

- ✓ Downsized turbocharged
- ✓ High CR naturally aspirated
- ✓ High BMEP

Transmissions

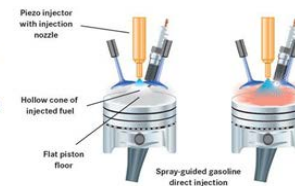
- ✓ AT – 8 and higher speed
- ✓ DCT – 7 and higher speed
- ✓ CVT – High ratio spread
- ✓ Early upshift strategies
- ✓ Shift optimization strategies

Architecture

- ✓ Conventional
- ✓ Mild hybrid (includes start/stop)
- ✓ Power-split hybrid
- ✓ P2 hybrid
- ✓ Plug in hybrid vehicles
- ✓ Extended range electric vehicle
- ✓ Electric vehicle

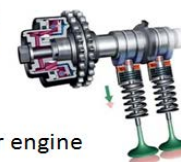
Key enabling technology for combustion efficiency

- ✓ Spray-guided GDI systems
- ✓ Wall-guided GDI systems with **multi-hole** injectors
- ✓ Added flexibility from **multiple injections**



Variable Valve Timing, Variable Valve Lift

- ✓ Over 95% of all vehicles have VVT/VVL



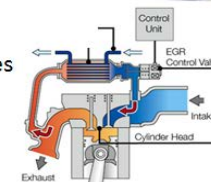
Turbocharging

- ✓ Trend toward higher BMEP and greater engine downsizing
- ✓ Single-stage, leading to two-stage



Next-generation combustion systems

- ✓ Dilute combustion (EGR): Reduce throttling losses and eliminate enrichment
- ✓ Lean burn (enabled by fuel sulfur control)
- ✓ Improved cold start emissions



12

e-Motors/Batteries

- ✓ Various lithium-ion types
- ✓ Permanent magnet motors
- ✓ Induction motors

Approach to Advanced Engine Testing



Engine benchmarking/development:

- ✓ **GDI engines** – a key enabling technology - are rapidly penetrating the market
 - i. Turbocharged & downsized engines
 - ii. High compression ratio naturally aspirated engines
- ✓ **Considering challenges:** turbo lag, engine stability, NVH

Technical Approach:

- ✓ Test engine **tethered to chassis** to take advantage of chassis controller
- ✓ Develop **operational maps** and reverse engineer engine control strategy
- ✓ Explore **limits of engine control** (eg: flexibility from multiple injections)
- ✓ Explore **new technology** independently and with supplier partnerships (eg: cooled EGR to reduce throttling losses and eliminate enrichment)



Cell 9 - tethered Ford Focus

Transmissions and Shift Logic

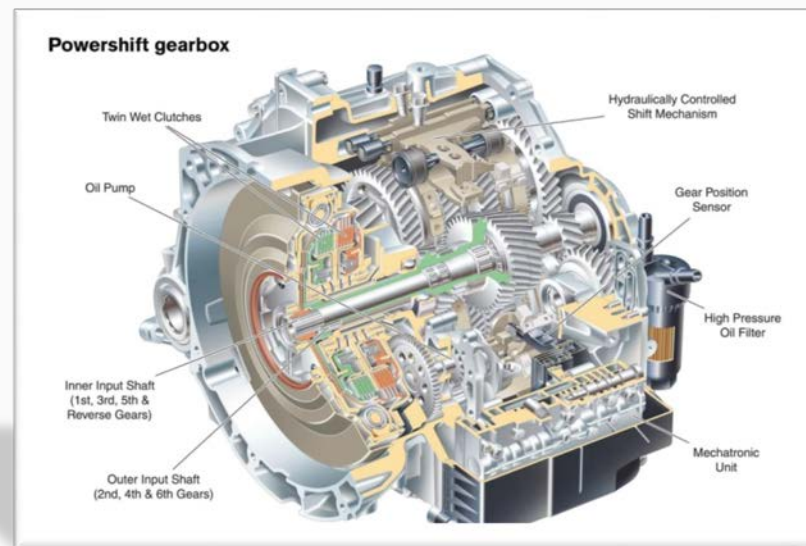


Transmission technology is evolving rapidly

- Over 60% of today's new vehicles have 6 or more gears
- Use of CVT's is growing rapidly
- Dual Clutch Transmissions (DCTs) are in the market

Controls (shift logic) are critical to effectiveness

- We are looking at efficiency attainable using advanced engines coupled with advanced transmissions/shift strategies
- Manufacturers are balancing efficiency, launch performance, NVH and customer acceptance



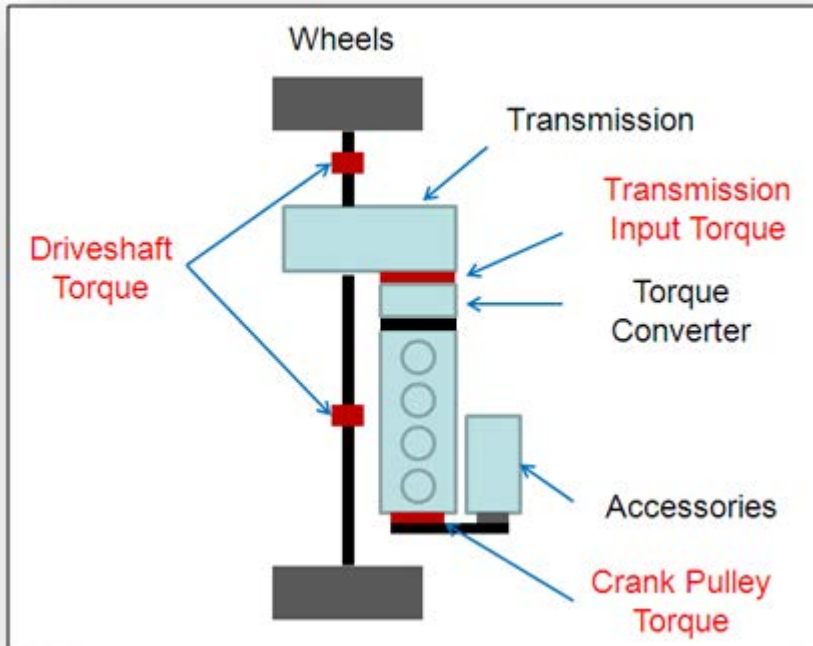
Dual Clutch Transmission

Reference: Getrag - <http://www.autolatest.ro/news-cars/getrag-is-doing-well-in-2012-turnover-rises-to-3-1-billion-euros>

Approach to In-Vehicle Benchmarking



Adding sensors to measure torques



Testing vehicles using various cycles

- ✓ Transient cycles on chassis dyno (FTP, HWFET, US06, etc...)
 - CO₂ and fuel consumption
 - Criteria pollutants
 - Battery state of charge
- ✓ Steady state operation on chassis dyno
 - Generate engine efficiency map
 - Generate transmission efficiency map
 - Characterize torque converter
- ✓ Vehicle speed sweeps on chassis dyno
 - Generate shift/timing maps
 - Torque converter lock-up

Monitoring operating CAN data

VW JETTA HYBRID SIGNAL LIST	
Engine Torque	Transmission Oil Temperature
Engine Speed	Transmission Gear Actual
A/F Ratio	Transmission Gear Commanded
Ambient Pressure	Transmission Output Shaft Speed
Ambient Temperature	Transmission Input Shaft Speed
Throttle Angle	Accelerator Pedal Position
Fuel Flow Rate Commanded	Brake Pedal Position
Fuel Flow Rate Measured	Vehicle Speed
Mass Air Flow	Hybrid Battery State of Charge
Intake Manifold Pressure	Hybrid Battery Voltage
Intake Manifold Temperature	Hybrid Battery Current
Exhaust Manifold Temperature	Emotor Voltage
Coolant Temperature In	Emotor Current
Coolant Temperature Out	Emotor Speed
Engine Oil Temperature	

Capturing wide range of data signals

- ✓ Added torque sensors
- ✓ Operating CAN data
- ✓ Other added instrumentation



Some of EPA's LD Vehicle Benchmarking Projects



Vehicles already tested:

2010 Toyota Prius

2011 Sonata Hybrid

2013 European Focus

Vehicles we are actively testing:

Automatic Transmission

- ✓ 2013 Chevrolet Malibu, 2.5L with 6-Speed
- ✓ 2013 Chrysler 300, 3.6L with 8-Speed
- ✓ 2012 Mercedes E350 BlueTEC (3.0L V6 Turbo Diesel with 7-Speed)

Continuously Variable Transmission

- ✓ 2013 Nissan Altima SV, 2.5L with CVT

Start/Stop Mild Hybrid

- ✓ 2013 Chevrolet Malibu Eco, 2.4L with 6-Speed and Belted Alternator Starter

P2 Hybrid

- ✓ 2013 VW Jetta Hybrid – Turbo P2 Hybrid with 7-Speed Dual Clutch Transmission

Extended Range Electric Vehicle

- ✓ 2013 Chevrolet Volt

Transport Canada (with EC & NRC Canada)

- ✓ 2013 Hyundai Sonata 2.0L Turbo 6-Speed AT
- ✓ 2012 Toyota Prius PHEV 1.8L, 4.4 kW-hr Lithium Ion Battery, 58 kW Electric Motor

Candidate vehicles we are considering testing:

2015 Acura TLX – 2.4 I4 GDI 206 Hp, 8-spd DCT w/ TC, maybe 9-spd

2014 BMW 3 Series – 2.0 I4 180 Hp, 8 Speed AT

2014 Ram 1500 HFE Regular Cab 4x2 – 3.6 V6 305 Hp, 8 Speed AT

2014 Jeep Cherokee Sport 4x4 – 2.4 I4 184 Hp, 9 Speed AT

- EPA plans to publish results on an ongoing basis.
- EPA can present detailed briefings at a future meeting with the Committee.

Vehicle Simulation Tool for the MTE



During the rulemaking...

- In agreement with the 2010 Committee's recommendations to utilize more vehicle simulation, EPA used Ricardo's proprietary vehicle simulation model to create a robust prediction of GHG emissions from future LD vehicles
- Model inputs were generated from Ricardo tests, modeling, experience & expertise
- Some source code, algorithms and model inputs are able to be shared

There are many options for performing vehicle simulations going forward, and more than one can be used to inform the MTE ...

- Public domain / university sources
- Independent laboratories
- OEM In-house Models
- Easy 5
- AVL CRUISE
- GT-Drive
- Autonomie
- EPA Modeling

Vehicle Simulation Tool for the MTE



Goals for EPA Modeling for 2022-2025 analysis...

- Faster turn around for adopting new information
- First-hand knowledge of future technologies and how they are captured in the simulations
- Create vehicle simulation models that would be more transparent using the **GEM*** and **ALPHA*** models for GHG compliance that were used for HD/MD trucks and GHG rulemaking for LD vehicles
- Apply EPA's extensive experience and expertise in testing, advanced technology and modeling
- Design both ALPHA and GEM models to share design, structure and code, developed by EPA in Matlab Simulink code (EPA began development in 2010)
- Validate models using data inputs generated from its in-house lab testing and other sources
- Share code, inputs and results with the public as much as possible

* **GEM** – Greenhouse Gas Emissions Model

* **ALPHA** – Advanced Light-Duty Powertrain and Hybrid Analysis

For more sources of information about GEM and ALPHA models, see publications list in the appendix slide.

Tools to Model Future Fleet



“Optimization Model for reducing Emissions of Greenhouse gases from Automobiles”

Lots of DATA!

Component Data

- ✓ engine
- ✓ transmission
- ✓ electrical components
- ✓ chassis, etc.

Vehicle Data

- ✓ steady-states
- ✓ transient cycles

ALPHA Model

Assesses Combinations of Light-Duty Technologies

- ✓ Quantifies effectiveness of a technology or groups of technologies
- ✓ Helps assess feasibility of light-duty standards

OMEGA is used to evaluate a future fleet's potential compliance path with LD GHG standards

- ✓ Feasibility analysis of how a fleet might utilize these technologies to comply with LD standards, not a market prediction
 - Manufacturer's engineering, marketing, or other considerations may lead them to a different path
 - Model assumes that technology availability and cost is equivalent across manufacturers
- ✓ Detailed fleet baseline on relevant technologies for ~1300 current models in the light duty fleet (modeled as ~250 vehicle platforms)
- ✓ Future vehicle sales are based on Economic projections from DOE/EIA, and Industry forecasts from JD Powers and CSM (Now IHS)

OMEGA Model

Assesses Potential Compliance Path with New LD GHG Rules

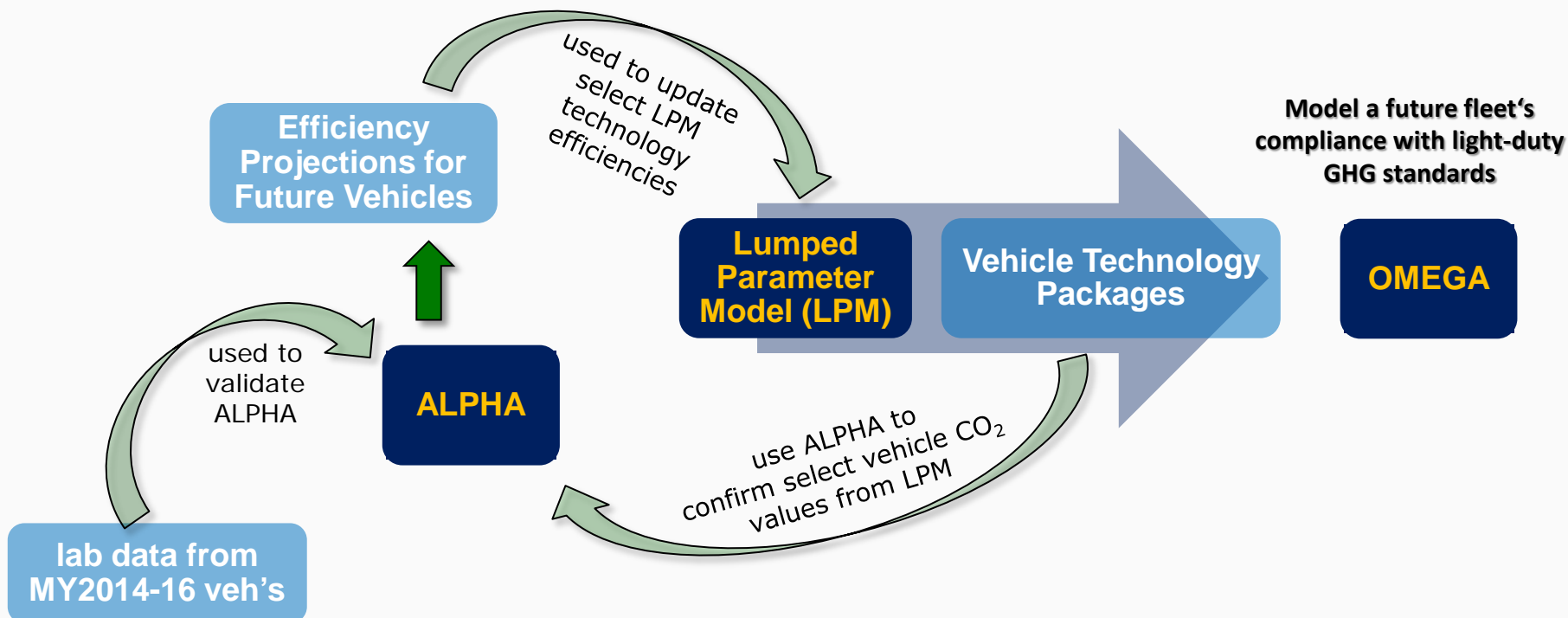
- ✓ Determines cost efficient path(s) of adding technology to vehicles in order to achieve regulatory compliance
- ✓ Quantifies economic and environmental impacts of technology changes/improvements in vehicle fleets
- ✓ Requires many scenarios of future vehicle technologies and their effectiveness (among many other model inputs) on reducing GHG emissions

Modeling Tools: ALPHA, Lumped Parameter Model (LPM) and OMEGA



Transparent processes will generate “technology effectiveness” inputs for the OMEGA model

- Use EPA lab and other data to validate ALPHA model
- Use ALPHA model to verify and supplement 2008 & 2011 Ricardo simulations
- Use ALPHA simulation results (and other data sources) to update LPM as appropriate
- Use LPM to generate vehicle technology packages (used as inputs to OMEGA)



Updates to the OMEGA Model



Since publishing final LD GHG rule for MYs 2017-2025, we have:

- Upgraded the technology tracking within OMEGA.
- Incorporated safety metrics into OMEGA so that fatality impacts are no longer a post-processed item.
- Updated costs for “transmissions” per revision by FEV in early CY2013, see EPA 420-R-13-007, located at:
<http://epa.gov/otaq/climate/documents/420r13007.pdf>
- Additional enhancements planned for 2014+, may include:
 - Plug-in electric vehicles (PEVs)
 - Monte Carlo uncertainty analysis capabilities
 - Potential to link with vehicle market consumer choice model



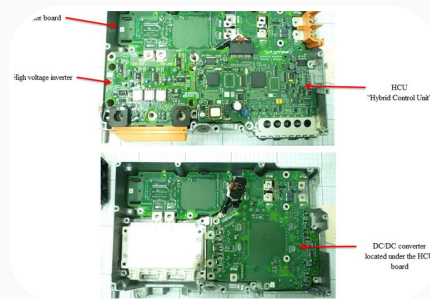
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Mild Hybrid Cost Teardown Study

- Study by FEV/Monroe to determine incremental cost from base vehicle to the vehicle using GM eAssist Mild Hybrid
- Draft study is complete and will soon undergo peer review
- Public release after peer review



2013 Malibu with eAssist



Electronics



Electro-Mechanical



Battery System



Packaging



Components

Diesel Cost Teardown Study



- Study to determine incremental cost to convert gasoline base vehicles to diesel for light duty through class 3
- Study to be completed in Q1 2015

Scope of study:

Category	Gasoline (base)	Diesel
LD Pass Car	VW Passat V6 3.0L VR6 DOHC	VW Passat TDI 2.0L I4 Turbo Diesel DOHC
LD Truck/SUV	Ford F150 5.4L 5.4L V8 SOHC	VW Passat TDI - Scaled 3.0L V6 Turbo Diesel DOHC

Other Potential Cost Teardown Studies



May include:

- Update of “assumptions” used in previous studies (i.e., new labor rates, materials, etc.)
- More recent GDI turbo downsized engine (looking at level of downsizing, more advanced turbo technology, and perhaps cooled EGR)
- Active grill shutters
- P2 hybrid, HEV and/or EV

Other Cost-related Issues



“Learning-by-Doing” impacts on manufacturing cost

- We have a contractor working on what we hope will add to the existing literature regarding “learning effects” in transportation industries
- A noted expert from Carnegie-Mellon, Dr. Linda Argote, is a subcontractor to that effort

Indirect costs

- We have quantified the indirect costs estimated by EPA in the MYs 2017-2025 final rule:
 - The prevailing assumption seems to be that EPA estimated indirect costs at roughly 25% of direct costs (i.e., total costs = 1.25 x direct costs)
 - This is not the case in the context of the MYs 2017-2025 GHG rules where total indirect costs were estimated to be roughly 50% of direct manufacturing costs (DMC)
- If there is interest, we can share the details of this analysis and the results



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EPA Light Duty Truck Light Weighting Study



Scope of Study

- Based on a 2011 4x4 Silverado 1500 Crew Cab
- Builds off of previous FEV/EDAG/Monro approach used for Toyota Venza, but with significant tailoring for a pickup truck.
- Addition of Dynamic and Durability analyses
 - Dynamic analyses done with instrumenting vehicle and running on test track
 - Includes bed and frame durability under loaded conditions



Draft/Final Report Timing:

- Undergoing peer reviewer this summer
- Will be publically released in Fall 2014/Winter 2015

Major deliverables for LD MTE

- Inform the development of a cost curve (\$/kg per %MR) for light weighting for light duty trucks (0-20%+MR)

Why a Truck Mass Reduction Study?



Trucks are different from Passenger Cars

- **Consumer Requirements**
 - Pulling/towing capacity
 - Possible rough terrain operation
- **Construction**
 - Body-on-frame (versus Unibody and “non-towing” trucks)
 - Many configurations (cabin/bed, engine size, etc.)

... May affect Mass Reduction cost and feasibility

- Less secondary mass reduction?
- The feasible materials and technologies?

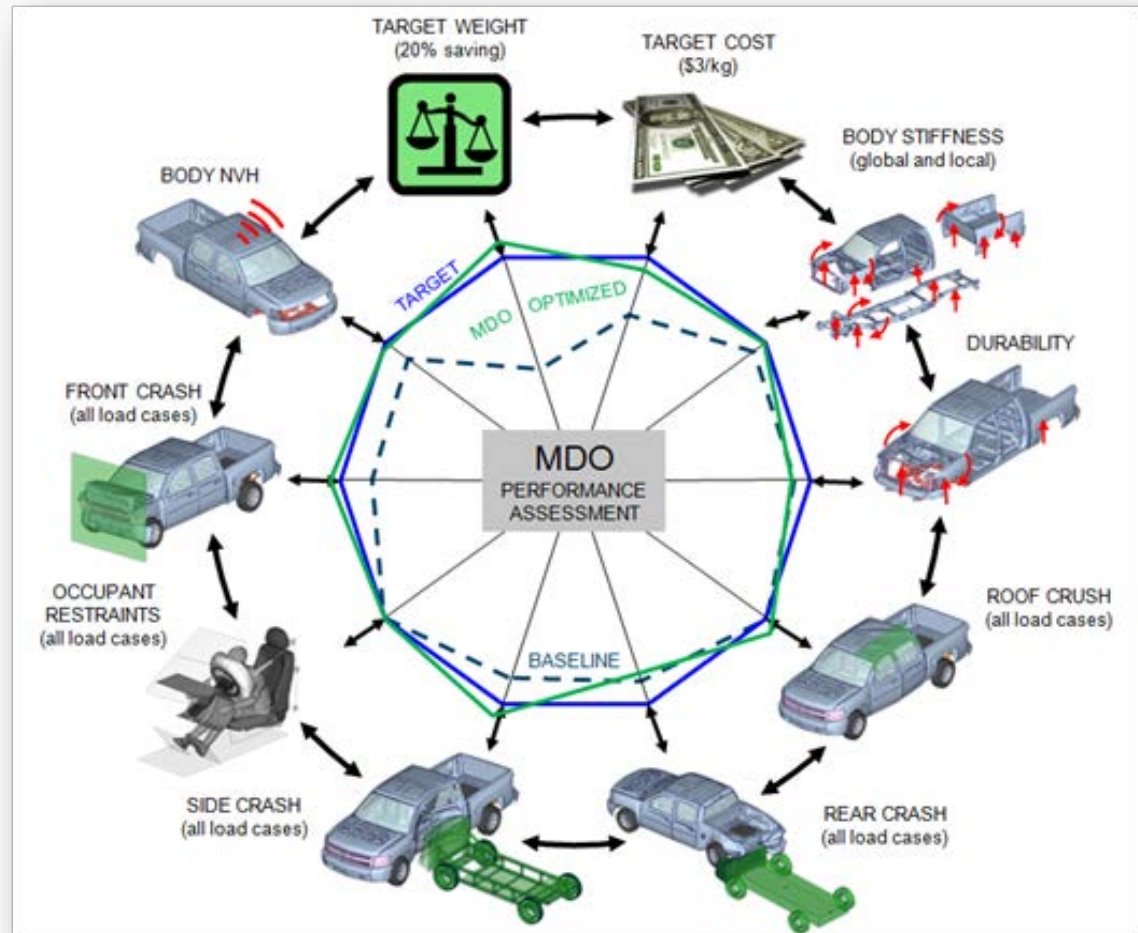
Boundary Conditions

- No degradation in function, performance (including payload and towing capacities), or safety from the baseline vehicle
- Capable of being mass-produced in the 2020-2025 timeframe (defined as 450,000 units per year)

Study's CAE Model Results



- The topics addressed in this analysis include the crash test simulations (front crash, side crash, rear crash, roof crush), NVH analysis and calculated \$/kg and the target weight (20%) mass reduction.
- The results are not yet final and so specific numbers cannot be relayed
- This spider plot illustrates the relative results of the redesigned light duty truck (green MDO Optimized) to the baseline truck (baseline is the dashed line).



Agenda



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Why Vehicle Choice Modeling



- **A consumer vehicle choice model can be used to better understand the potential effect of vehicle GHG/fuel economy standards on**
 - Vehicle sales
 - Fleet mix
- **In the 2012-16 LD GHG rule, EPA reviewed literature on vehicle choice models* and found:**
 - Dozens of models
 - Great variation in data sets, methods, variables considered
 - Almost no comparison of results from different models
 - Almost no assessment of the models' predictive abilities
- **For the 2017-25 LD GHG rule, EPA developed a vehicle choice model**
 - It was not used in the analysis because we believed testing was needed to have confidence in its use and results.

**source: Helfand and Wolverton, International Review of Environmental and Resource Economics 5 (2011) pgs 103-146*

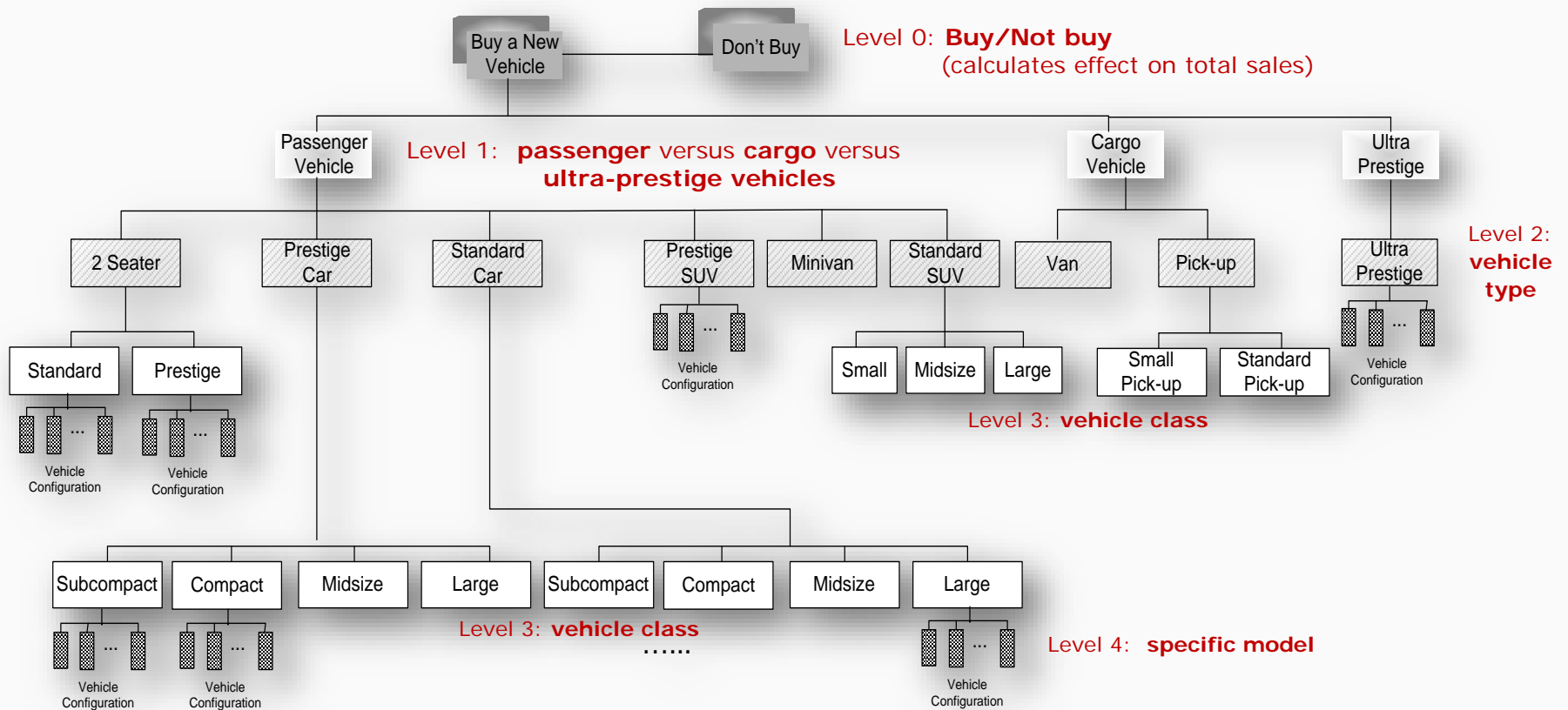
EPA's "Vehicle Choice" Model



- **EPA contracted with Oak Ridge National Lab** to develop a vehicle choice model for use in GHG rules (David Greene, Changzheng Liu)
 - <http://www.epa.gov/otaq/climate/documents/420b12052.pdf>
- **Initial version of the model – a nested logit** -- *completed in 2012*
 - Closer substitutes are in the same nest
 - Sales respond to changes in net price
 - Net price is the change in vehicle cost less a share of future fuel savings
 - Other vehicle attributes are assumed to stay constant
 - It has been integrated with OMEGA
- **Updated version includes plug-in electric vehicles (PEV)**
 - Structure is the same as the initial model
 - Novel features include adjustable parameters for
 - Cost of limited range
 - Cost of refueling time for conventional and plug-in vehicles
 - Some consumers want novel technologies, others avoid them
 - We are working to integrate it with OMEGA

Model Structure

A Nested Logit



Testing the Model



EPA is conducting a validation exercise with the non-PEV version of the model

- Putting it through its paces: running defined scenarios to see magnitudes of impacts due to model choices
 - Payback period, discount rate, demand elasticities
- Calibrating the model to MY 2008 sales, and testing its ability to predict MY 2010 sales
 - Those are the baseline years in the LD GHG 2017-25 vehicle rule analysis.
 - We may attempt to validate with other model years as well.
- We aim for a working paper this summer



Consumer responses to fuel-saving technologies

- Content analysis of auto reviews
 - Content analysis is a systematic way to analyze texts
 - The plan is to analyze published auto reviews to see whether professional reviewers describe the new technologies as positive or negative attributes.
- Consumer satisfaction surveys
 - Conducted by market research firms
 - We are assessing whether these surveys can provide statistically valid insights into effects of the standards on consumer satisfaction
- The work is just beginning

Rebound

- Estimate of the increase in VMT associated with an increase in fuel economy
- EPA commissioned and is finishing peer review of new work by Ken Small (UC-Irvine) and Kent Hymel (CSU Northridge)



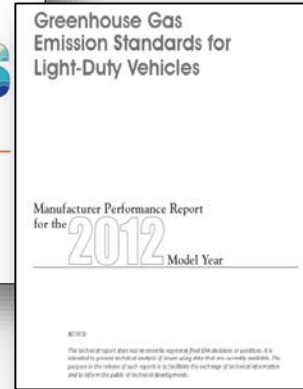
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Continuing to Track Commercialization Trends



What trends are we following?

- Technology availability and applications to vehicles
 - Building upon Fuel Economy Trends data
 - Monitor fleet-wide tech availability/penetration (electric power steering, active grill shutters, start/stop, lightweight materials...)
- Vehicle characteristics
 - Technical specifications (gear ratio spreads, torque, compression ratio...)
 - Performance (towing/hauling capacities, acceleration...)
 - Dimensional (overall vehicle size, frontal area, fr/rr overhangs, curb weights...),
- Related manufacturing issues
 - Platform sharing
 - Redesign cadence
- Compliance and credits
 - Annual EPA GHG Performance Report

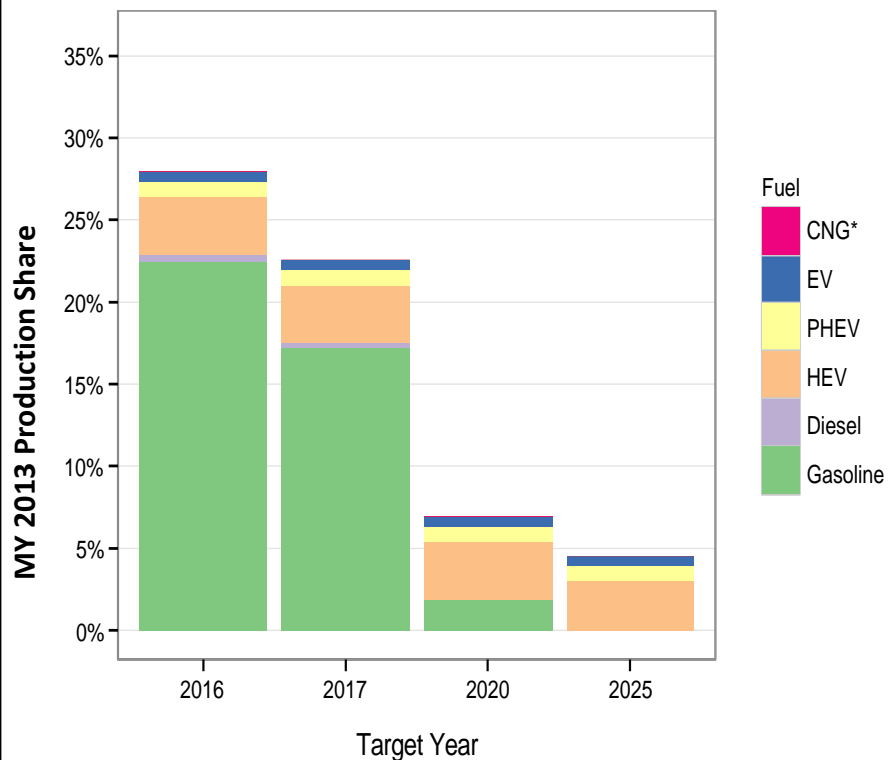


Commercialization Trends

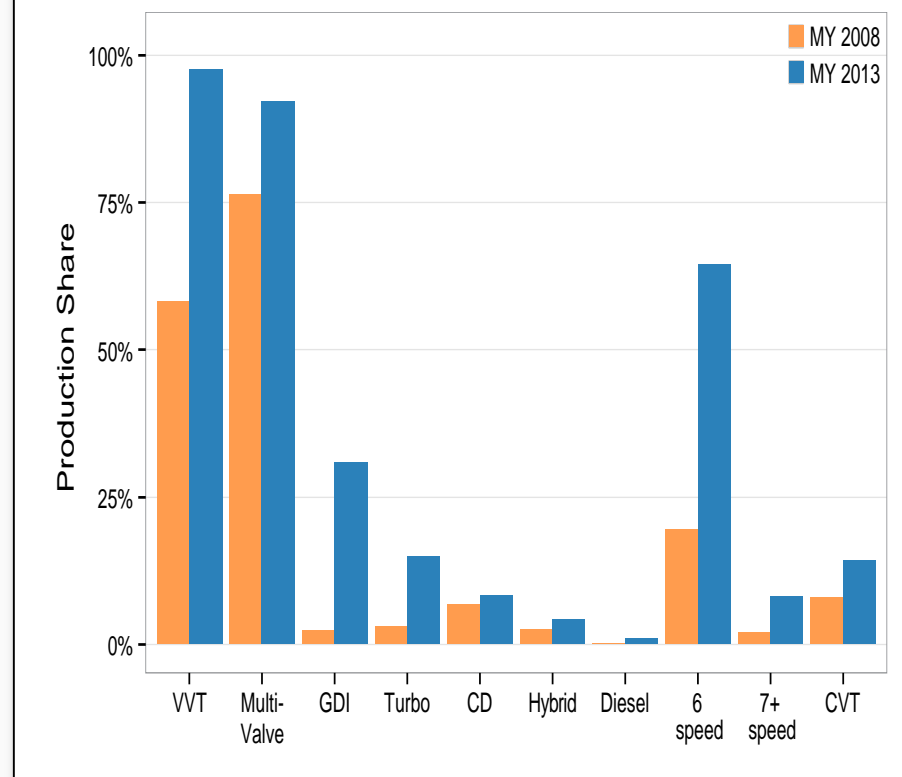


We draw data from existing EPA data (VERIFY, FE Trends, GHG performance report), third party and original data, industry and popular press.

2013 Vehicles Meeting Future CO₂ Targets by Projected Sales



Advanced Gasoline Technologies Rapidly Gaining Market Share



Nearly 35% of projected MY 2014 production already meets Model Year 2016 targets

Potential Topics for Follow-up Meeting in Ann Arbor if Committee is Interested



- **Technology Assessment and Modeling Tools**
 - Lab review of our engine and in-vehicle benchmarking
 - EcoBoost engine map/data
 - Autoshift simulation data
 - ALPHA validation results
- **Technology Cost Analysis**
 - Results of recent cost teardown of mild hybrid
 - Indirect cost multipliers (ICM assessment from 2017-2025 rule)
 - Details of pre-peer reviewed results from FEV/EDAG mass reduction study on GM Silverado
- **Consumer Issues**
 - Consumer vehicle choice model validation results
 - Description of content analysis and consumer satisfaction survey studies

Appendix: 2013/2014 MTE Related EPA/OTAQ Publications



2013 -----

- Byungho Lee, SoDuk Lee, Jeff Cherry, Anthony Neam, James Sanchez, Edward Nam, "**Development of Advanced Light-Duty Powertrain and Hybrid Analysis Tool**", SAE Technical Paper 2013-01-0808.
- Cheryl Caffrey, Kevin Bolon, Hugh Harris, Greg Kolwich, Robert Johnston, Tim Shaw, "**Cost-Effectiveness of a Lightweight Design for 2017-2020: An Assessment of a Midsize Crossover Utility Vehicle**", SAE Technical Paper 2013-01-0656.
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