Midterm Evaluation of the 2022-2025 Light Duty GHG Standards

Review of Technical Assessment and Role of Off-Cycle Credits

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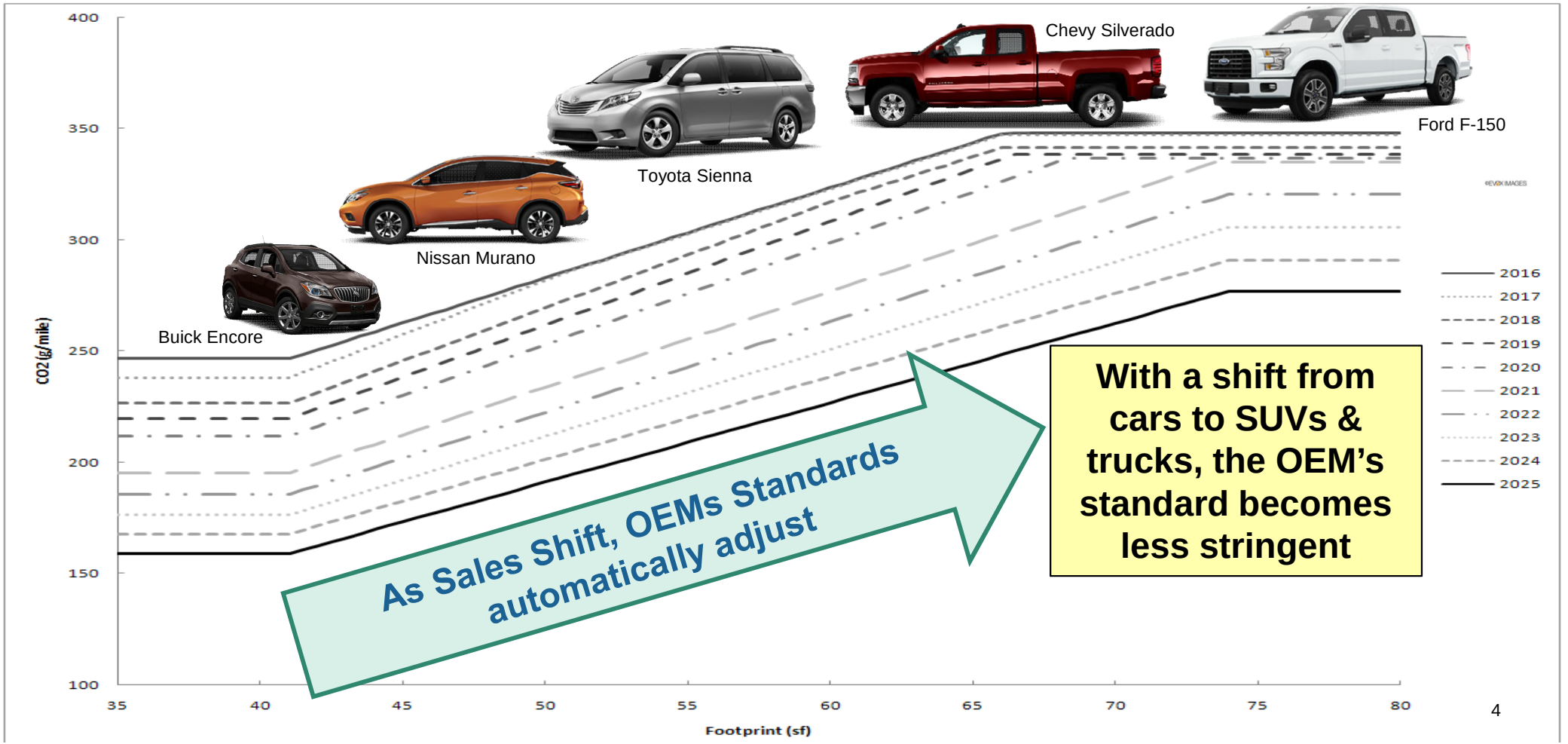
Overview

- **How the EPA GHG Standards Work**
- **GHG Program Flexibilities**
- **Progress-to-Date and Contribution of Flexibilities**
- **What Might the 2025 Time-Frame Look Like**
  - EPA assessment (thus far)

How the EPA standards work

Footprint-based CO_2 Target Curves for Trucks – "The Standards"

[separate footprint curve for Cars]



So What is the 2025 EPA Standard?

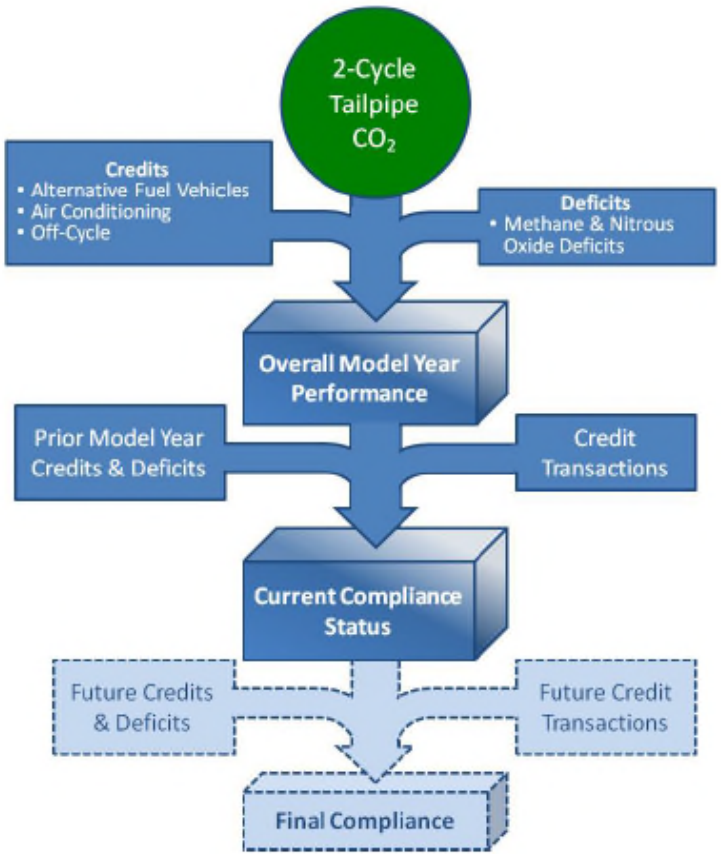
Projections for Model Year 2025 Fleet CO2 Compliance Target
Fuel Prices/Fleet Mix Affect EPA's PROJECTION of 2025 Standard

	2012 Projection	Summer 2016 Projection	Fall 2016 Projection
Fuel Price ($/gallon)	$3.87	$2.95	$2.97
Car/truck mix	67/33%	52/48%	53/47%
2025 Fleet CO_2 Compliance Level (g/mi, 2-cycle)	163	175	173
MPG-e (2-cycle)	54.5	50.8	51.4

GHG Program Flexibilities

Compliance Determination with Credit Banking and Trading

- **Assist manufacturer planning and phase-in of GHG-reducing technologies, consistent with typical redesign cycles**
- **Unlimited credit transfer across car and truck fleets**
- **Unlimited credit trading between manufacturers**
- **5-year credit carry-forward, with one-time early credit carry forward of CO_2 credits**
  - MY 2010 and later credits can be carried forward to MY 2021
- **3-year credit carry-back**



Off-cycle Credits

Overview

- Technologies that achieve real-world GHG reductions, but are not captured on 2-cycle city/highway tests
- List of a subset of technologies and pre-approved credit levels (e.g., active aerodynamics, high efficiency lighting, solar panels) beginning in MY 2014
- Manufacturers may apply for more credits or other technologies based on sufficient data

Three-pathways for obtaining off-cycle credits

- Defined Technology List
- 5-cycle test comparison
- Alternative demonstration method, requiring:
  - modeling, data collection, or other analytical or engineering method
  - verifiable demonstration with strong statistical significance
  - applicability over wide range of driving conditions and number of vehicles

Off-Cycle Credit Defined Technology List

Technology	Cars (g/mi)	Trucks (g/mi)
High Efficiency Exterior Lights (at 100 watt savings)	1.0	1.0
Waste Heat Recovery (at 100W)	0.7	0.7
Solar Panels (based on a 75 watt solar panel);		
Battery Charging Only	3.3	3.3
Active Cabin Ventilation and Battery Charging	2.5	2.5
Active Aerodynamic Improvements (for a 3% aerodynamic drag or Cd reduction)	0.6	1.0
Engine Idle Start-Stop;		
w/ heater circulation system	2.5	4.4
w/o heater circulation system	1.5	2.9
Active Transmission Warm-Up	1.5	3.2
Active Engine Warm-up	1.5	3.2
Solar/Thermal Control	Up to 3.0	Up to 4.3
Total Theoretical Credits; Non-Hybrid Vehicles *(Ignores synergistic effects)*	10.8	17.8
HEVs/PHEVs/EVs *(Ignores synergistic effects)*	14.1	21.1
Credit Cap	10 (fleet-wide car/truck average)	

Off-Cycle Credit Defined Technology List: Solar/Thermal Control Technology Credit Values

Technology	Credit for Cars	Credit for Light Trucks
	g/mi	g/mi
Glass or Glazing	Up to 2.9	Up to 3.9
Active Seat Ventilation	1.0	1.3
Solar Reflective Paint	0.4	0.5
Passive Cabin Ventilation	1.7	2.3
Active Cabin Ventilation	2.1	2.8
Total Theoretical Credits:	8.1	10.8
Credit Cap:	Up to 3.0	Up to 4.3

Air Conditioning Improvement Credits

Low-Leak Components (reduce HFCs)

Seal washers

Low-permeation, barrier hose

Alternative Refrigerants (reduce HFCs)

- R-744 (CO2)
- R-152a
- HFO-1234yf

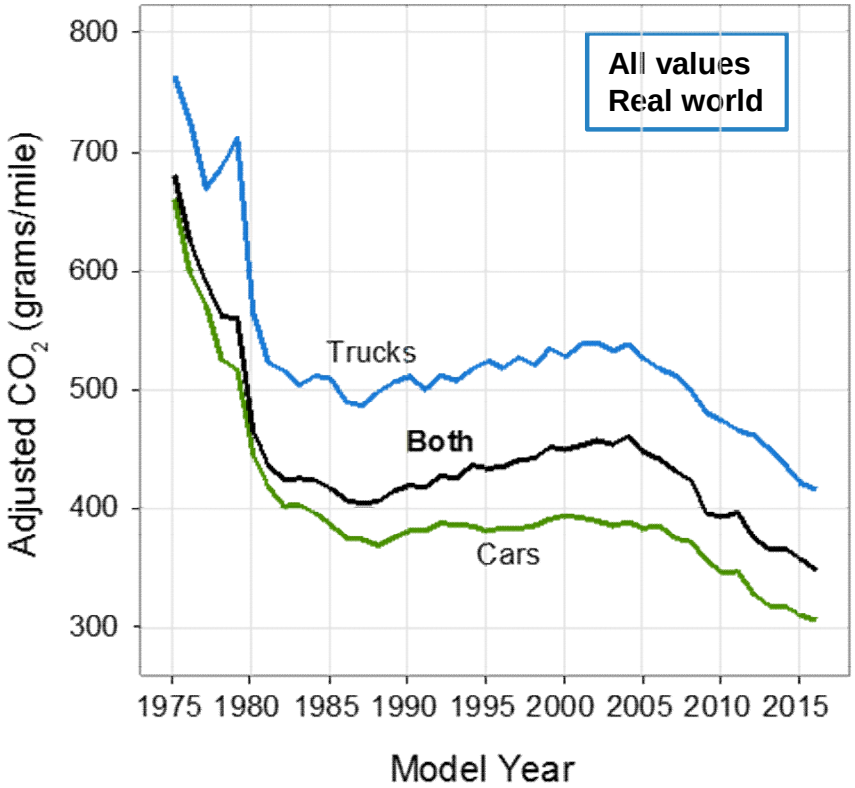
Improved System Efficiency (reduce CO2 & fuel consumption)

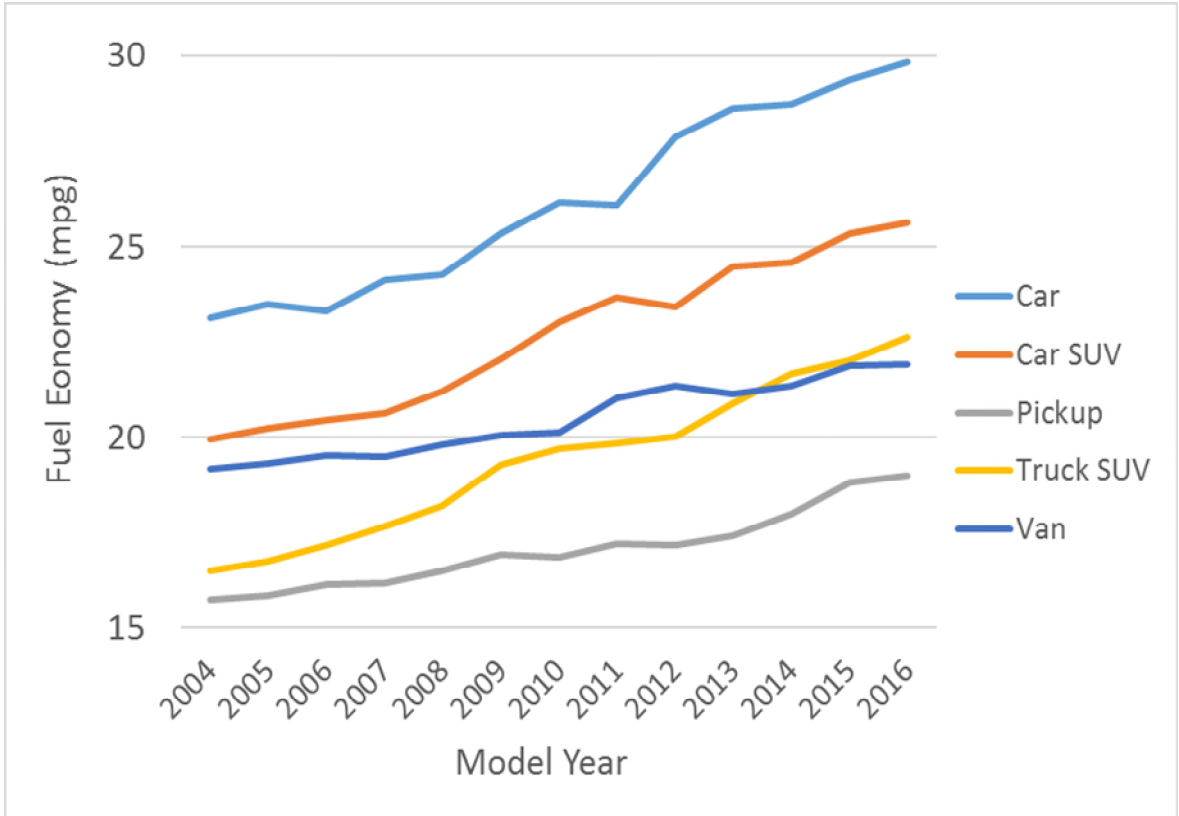
Variable compressor + reduced reheat

Improved blower motor controls

Progress-to-Date and Contribution of Flexibilities

Vehicle CO_2 Emissions at Record Low – every major vehicle category improving



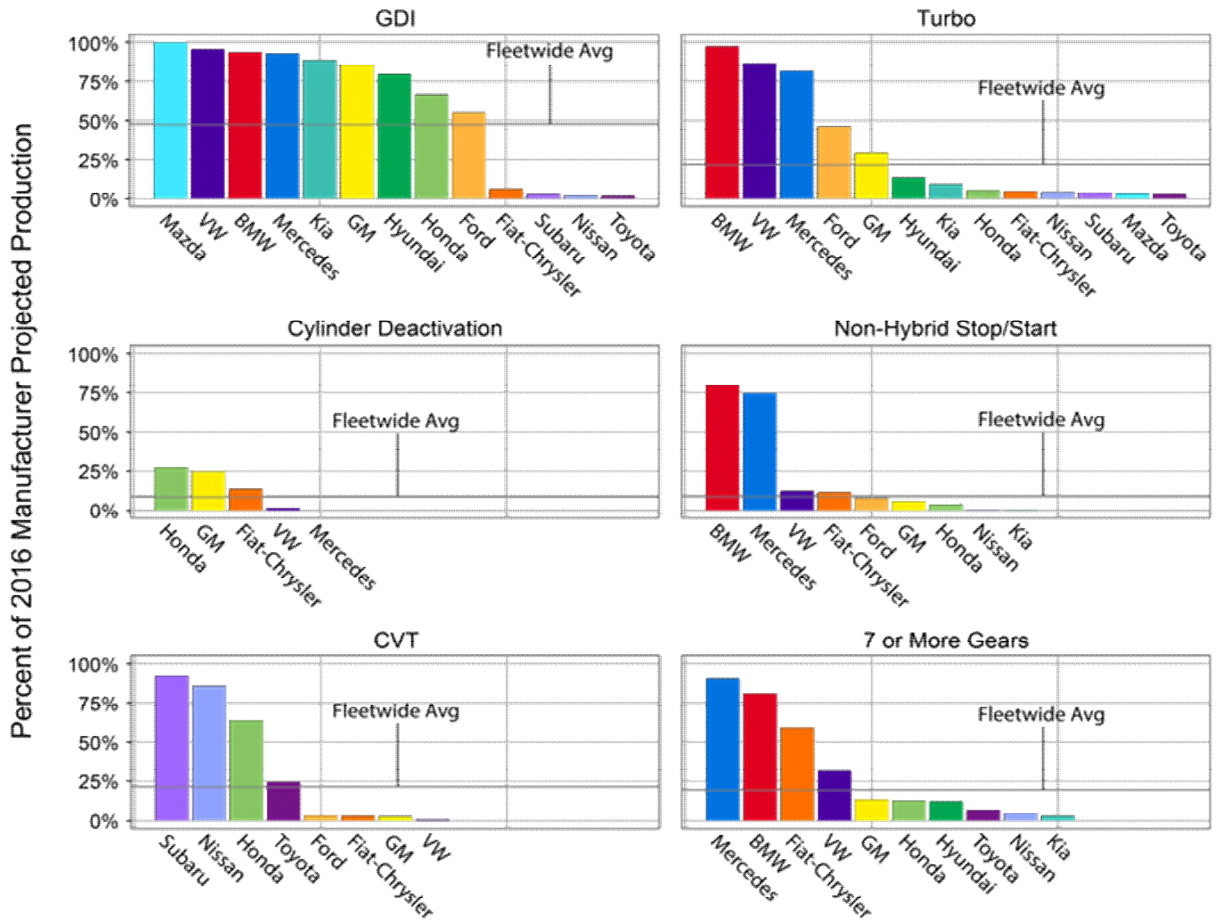


MY2015: 358 g/mi CO_2 (24.8 mpg)
MY 2016 Projected : 25.6 mpg

Truck SUVs highest % improvement since 2004, up 33%
Pickups improved most in past year, up 0.8 mpg to 18.8 mpg

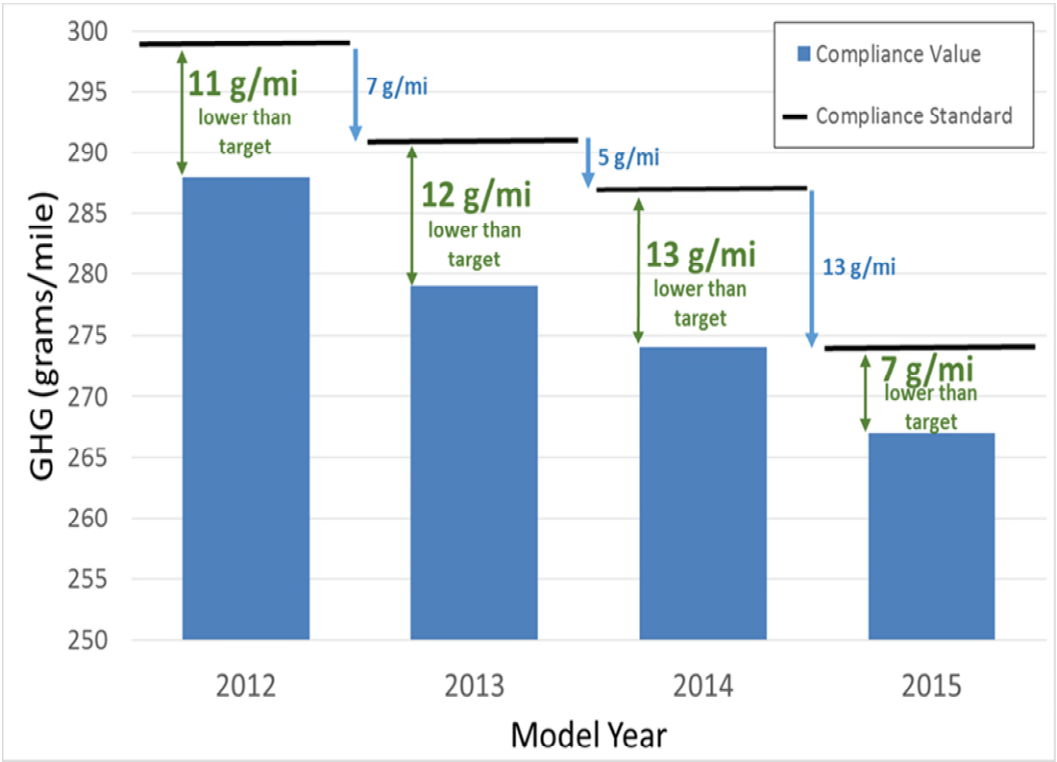
Automakers Adopting a Wide Array of Technologies at Rapid Rates

- **GDI** use on nearly half of all vehicles (up from 3% in MY2008), with Mazda at 100%, 6 more OEMs above 75%
- ~20% fleet use **7+ speed transmissions**, led by Mercedes, BMW, and Fiat-Chrysler
- >20% fleet use **CVTs**, led by Subaru, Nissan, and Honda

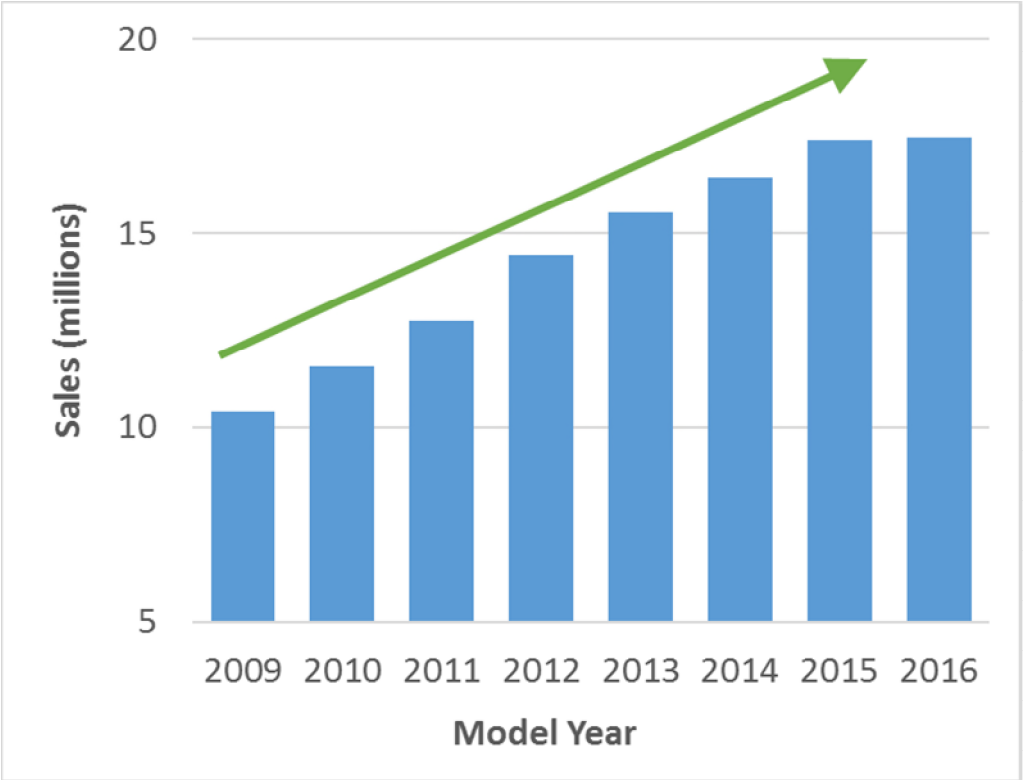


Early Years of Program Producing Positive Results

Industry Outperforming Standards



7 Years of Sales Increases Thru 2016
First Time in 100 Years



What Happens to the Over Compliance?

GHG Program is a Multi-Year Program, multiple layers of flexibility for OEMs

- No single year determines compliance.
- Program includes emissions banking and trading
- Credits last at least 5 model years, and early credits last longer.
- Debits can be carried forward for 3 model years.
- Today, the bank is **280 Million Megagrams CO2**
  - What's a Megagram?
  - 280M worth about **80 grams CO2/mile** for the entire U.S. fleet
  - Would allow the MY2015 fleet to comply with EPA standards through 2019, if all firms participated fully in credit trading
  - Through MY2015, 12 OEMs involved in credit trading

MY2015 Credits: Off-cycle

Source: US EPA, "Manufacturer Performance Report for the 2015 Model Year" EPA 420 R 16 014, November 2016

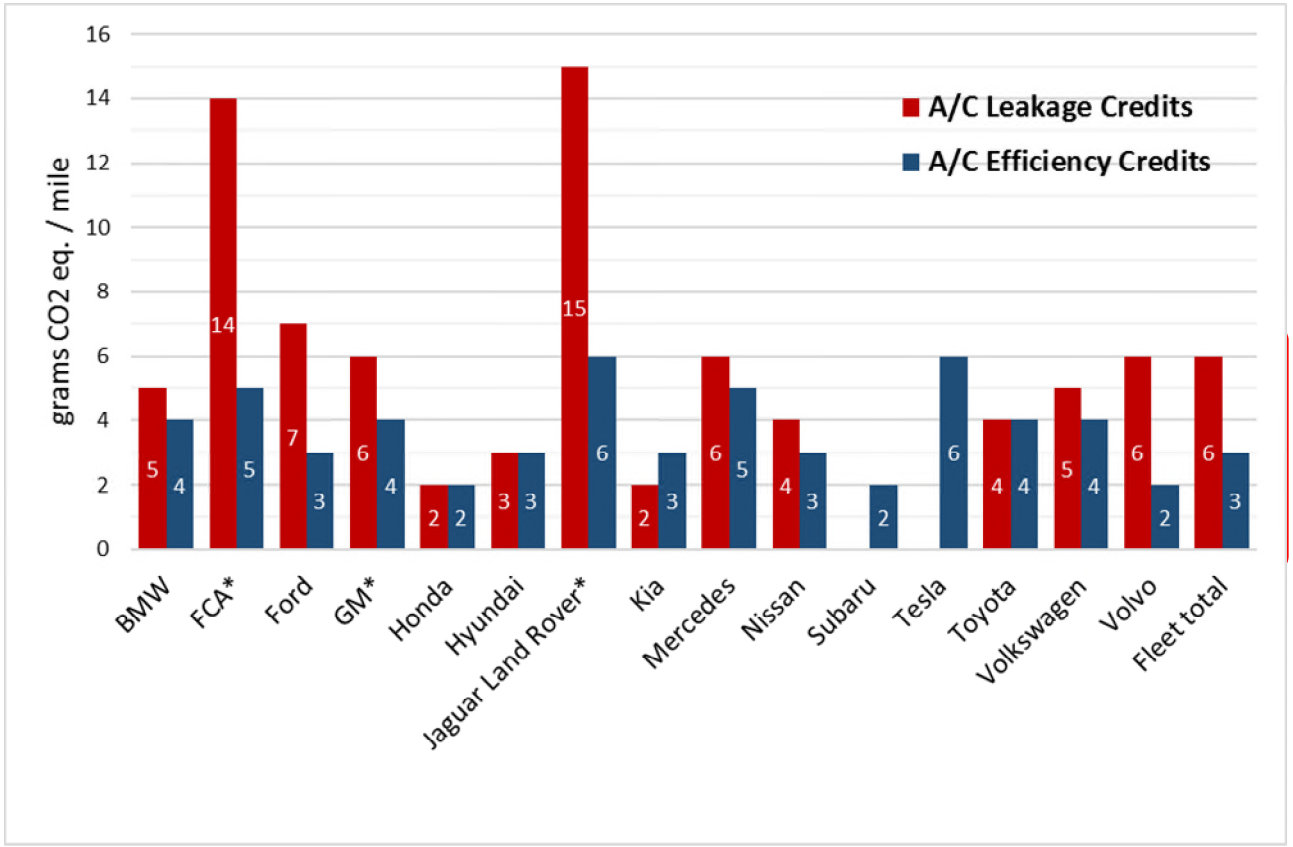
Table 3-21. Model Year 2015 Off-Cycle Technology Credits from the Menu, by Manufacturer and Technology (g/mi)

	Active Aerodynamics		Thermal Control Technologies					Engine & Transmission Warmup		Other			
Manufacturer	Grill shutters	Ride height adjustment	Passive cabin ventilation	Active cabin ventilation	Active seat ventilation	Glass or glazing	Solar reflective surface coating	Active engine warmup	Active transmission warmup	Engine idle stop-start	High efficiency exterior lights	Solar panel(s)	Total
BMW	-	-	-	2.1	0.1	0.0	-	1.5	-	-	0.6	-	4.2
FCA	0.2	0.0	1.9	-	0.0	1.6	0.0	1.6	0.4	0.2	0.2	-	6.1
Ford	0.7	-	2.0	-	0.3	-	-	1.2	0.7	0.4	0.3	-	5.6
GM	0.0	-	-	-	0.2	1.4	0.1	0.2	-	0.1	0.2	-	3.0
Honda	-	-	-	-	0.0	-	-	-	1.4	0.0	0.1	-	1.5
Hyundai	0.0	-	-	-	0.2	0.4	-	-	0.8	-	0.0	-	1.5
Jaguar Land Rover	-	-	-	-	0.6	1.2	-	-	-	2.6	0.5	-	4.9
Kia	0.0	-	-	-	0.2	0.6	-	-	0.2	0.0	0.1	-	1.2
Nissan	0.1	-	-	-	0.0	-	0.1	0.4	1.3	0.0	0.1	0.0	2.0
Subaru	0.1	-	-	-	-	-	-	-	-	-	0.0	-	0.2
Toyota	-	0.0	-	-	0.3	0.7	0.1	0.1	0.9	0.2	0.2	-	2.5
Fleet Total	**0.1**	**0.0**	**0.5**	**0.1**	**0.1**	**0.6**	**0.1**	**0.5**	**0.6**	**0.1**	**0.2**	**0.0**	**2.8**

Note that "0.0" indicates that the manufacturer did implement that technology, but that the overall penetration rate was not high enough to round to 0.1 g/mi, whereas a dash indicates no use of a given technology by a manufacturer.

MY2015 Credits: A/C Leakage and Efficiency

Source: US EPA, "Manufacturer Performance Report for the 2015 Model Year" EPA 420 R 16 014, November 2016



What might 2025 look like: EPA technical assessment (thus far)

EPA's Assessments are Informed by a Wide Range of Information

Technical research performed by EPA

- Benchmarking testing of **30 vehicles** across wide range of powertrains & segments (with more to come)
- Published more than **30 peer-reviewed papers and technical reports**
- Vehicle simulation modeling, cost teardown studies, mass reduction feasibility/cost studies, manufacturer "learning by doing" costs, research on consumer issues, economic inputs, others

Extensive reviews of the literature

- **100's of reports/papers** from the literature published since 2012, including major studies such as the 2015 National Academy of Sciences report

Stakeholder outreach & collaboration

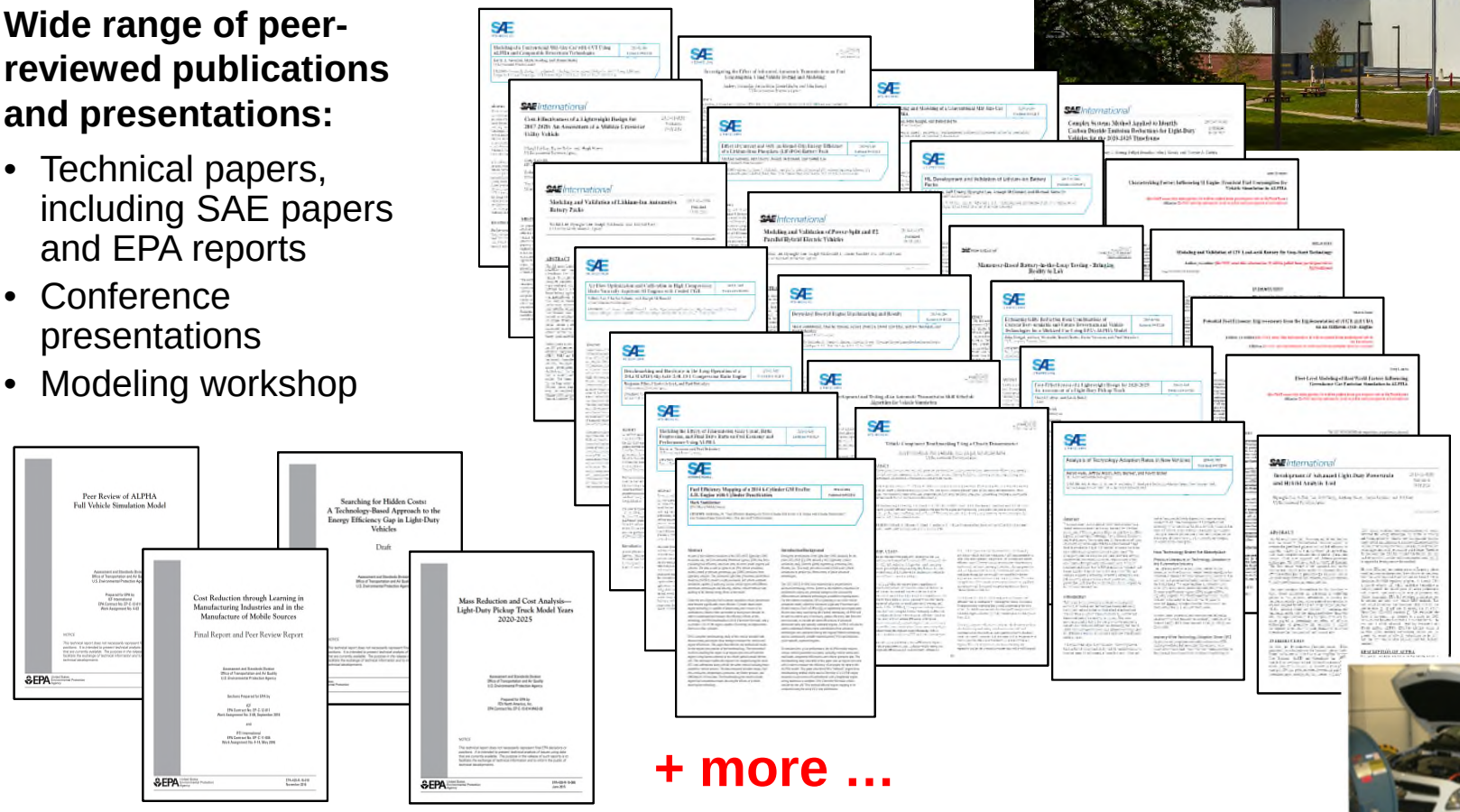
- Hundreds of meetings with automakers, suppliers, NGOs, consumer groups, labor, states/local governments, others
- Collaboration with NHTSA, CARB, DOE, Transport & Environment Canada

EPA technical information available to all stakeholders/public

EPA's National Vehicle and Fuel Emissions Laboratory Ann Arbor, MI

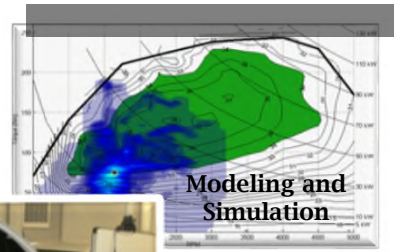
Wide range of peer-reviewed publications and presentations:

- Technical papers, including SAE papers and EPA reports
- Conference presentations
- Modeling workshop



+ more …


Tethered Engine testing


Modeling and Simulation


Vehicle Dyno testing

EPA Most Recent Assessment of MY2025–
Standards can be Met Mostly with Advanced Gasoline Technologies

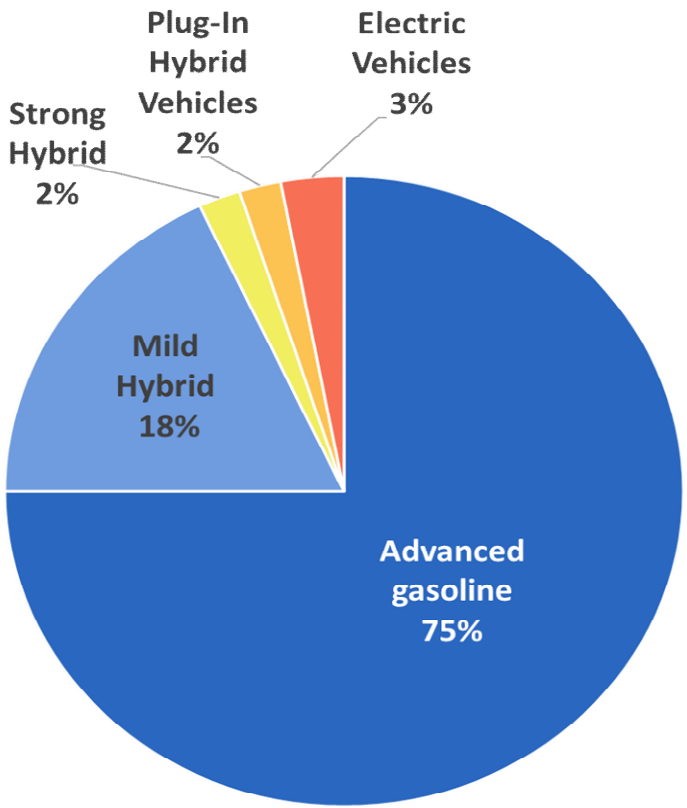
Cost estimate of $875/vehicle

- ✓ Advanced engines and transmissions
- ✓ Vehicle light-weighting
- ✓ Improved aerodynamics
- ✓ More efficient accessories
- ✓ Low rolling resistance tires
- ✓ Stop-start technology
- ✓ Mild hybrid (e.g., 48 volt systems)
- ✓ Small levels of strong HEV, EV, PHEV
- ✓ 2.7 g/mi Off-cycle Credits
- ✓ 21.4 g/mi A/C Credits

Fuel Savings Offsets Cost increase

- ✓ Net lifetime savings of $1,650

One possible pathway EPA modeled



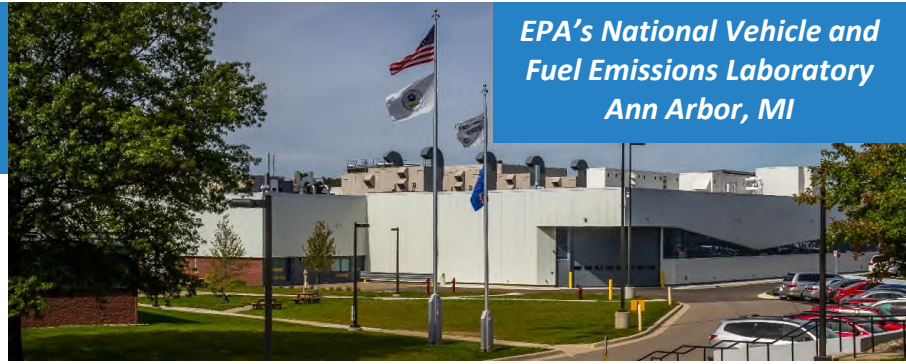
EPA's Reconsideration of the MTE Final Determination

March 15, 2017 - EPA Administrator Pruitt issued a Notice announcing he will reconsider the EPA Final Determination published in January 2017:

" … EPA has concluded that it is appropriate to reconsider its Final Determination in order to allow additional consultation and coordination with NHTSA in support of a national harmonized program."

"In accord with the schedule set forth in EPA's regulations, the EPA intends to make a new Final Determination regarding the appropriateness of the MY 2022-2025 GHG standards no later than April 1, 2018."

EPA Continues its In-depth Evaluation of Advanced Powertrains



Component benchmarking efficiency maps:

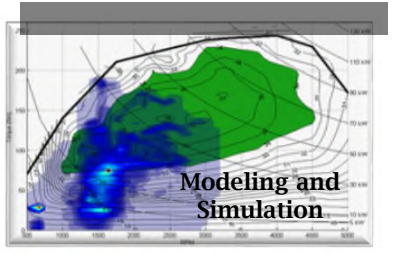
- MY2016 Mazda CX-9 2.5 liter GDI-turbo-charged w/ 6-speed AT
- MY2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 w/ CVT

Vehicle level benchmarking:

- MY2016 Acura ILX w/dual-clutch transmission with torque converter
- MY2017 Ford F150 w/10 speed AT
- MY2016 Chevy Malibu w/1.5 liter GDI-turbo-charged w/ 6-speed AT

Demonstration and Modeling:

- Demonstration of cooled EGR on a modified European Mazda 2.0 liter GDI-naturally-aspirated 14:1 CR engine
- GTPower modeling of a MY2012 PSA 1.6 liter GDI-turbo-charged engine with cooled EGR and an advanced turbo
- GTPower modeling of a MY2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 CR engine
- ALPHA model comparison of several CVTs
- ALPHA modeling of all vehicles included in above component and vehicle benchmarking



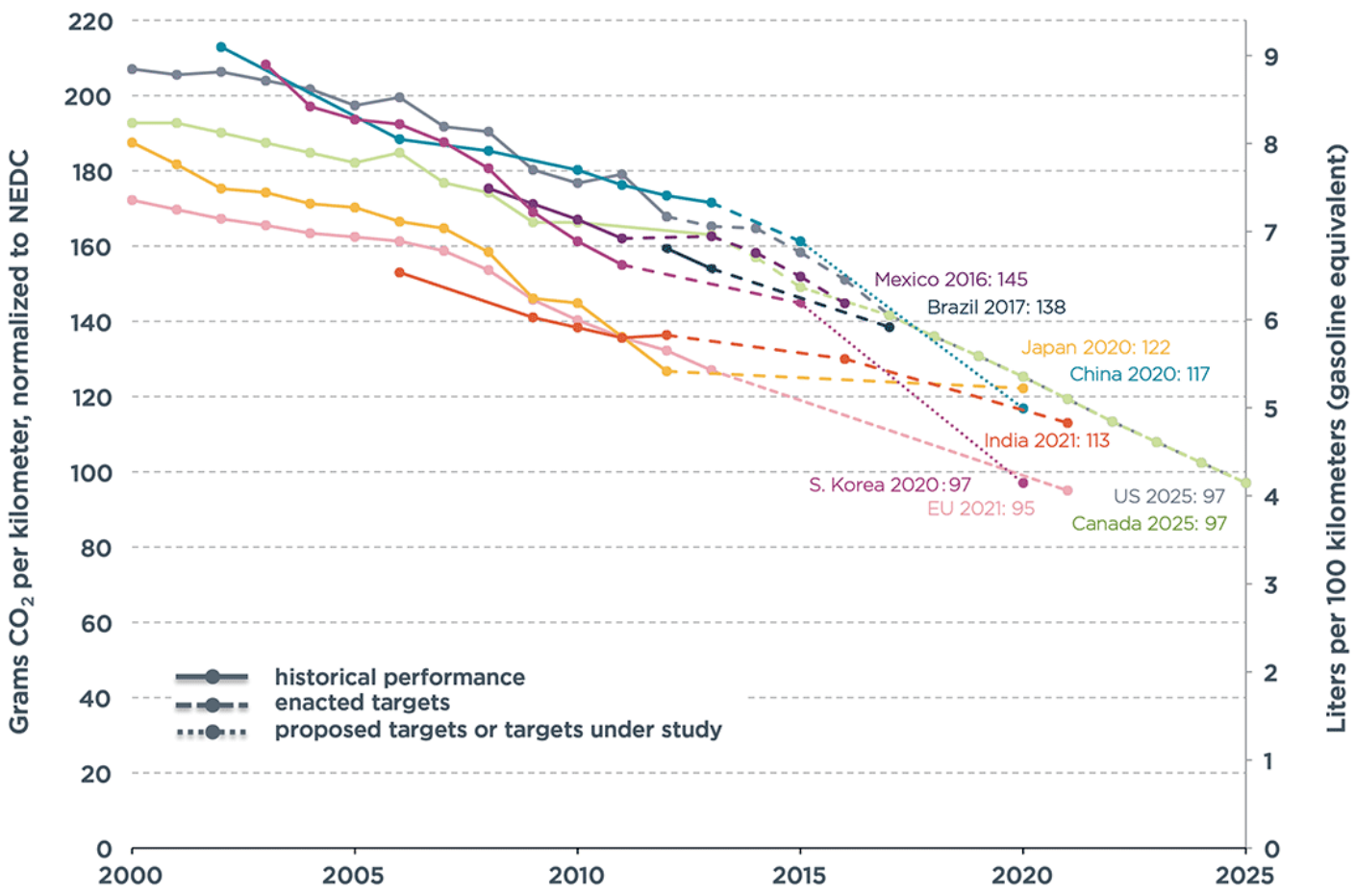
Modeling and Simulation

Additional EPA Work Underway in Many Areas

- **Technology cost teardowns with FEV**: modern GDI turbo-downsized engine, advanced diesel engine, CVT
- Updates to OMEGA **cost-effectiveness optimization model** and ALPHA **full vehicle simulation model**
- Ongoing work to evaluate the **willingness to pay (WTP) for vehicle attributes** (e.g., power, fuel economy, size, etc).
  - Our review of 50+ papers from the last 20 years found very wide variation in these WTP values. Ongoing work evaluates what factors may contribute to this variation.
- **Ongoing evaluation of automotive reviews of MY2015 vehicle fuel efficient technologies**
  - Building upon EPA's study of MY2014 vehicles, we continue to find that positive evaluations for all technologies (70%) exceed negative evaluations of the technologies (18%)
- **Ongoing work to evaluate the vehicle miles traveled (VMT) rebound effect**
- Collaboration with Transport and Environment/Climate Change Canada on **mass reduction** and **aerodynamics**
- Continued evaluation of the vehicle fleet each year to assess technologies, emissions, and compliance
  – supporting EPA's forth-coming **MY2016 Manufacturer GHG Performance Report** and **2017 CO2/Fuel Economy Trends Report**

Appendix

Global Passenger Car CO2 Standards



Source: International Council for Clean Transportation.

http://www.theicct.org/blogs/staff/improving-conversions-between-passenger-vehicle-efficiency-standards

MY2015 Credits: A/C Leakage and Efficiency

Source: US EPA, "Manufacturer Performance Report for the 2015 Model Year" EPA 420 R 16 014, November 2016

Table 3-12. Reported A/C Leakage Credits by Manufacturer and Fleet, 2015 Model Year (Mg)

Manufacturer	Car	Truck	Total	Grams/mile Equivalent of Total Credits
BMW	298,951	136,661	435,612	5
FCA*	1,904,927	4,672,447	6,577,374	14
Ford	1,087,338	1,685,004	2,772,342	7
GM*	1,643,372	2,274,024	3,917,396	6
Honda	315,425	486,133	801,558	2
Hyundai	301,255	33,642	334,897	3
Jaguar Land Rover*	27,395	209,062	236,457	15
Kia	260,945	32,421	293,366	2
Mercedes	246,447	192,528	438,975	6
Nissan	900,624	656,279	1,556,903	4
Toyota	1,132,635	1,111,424	2,244,059	4
Volkswagen	435,715	179,463	615,178	5
Volvo	43,455	42,782	86,237	6
Fleet Total	8,598,484	11,711,870	20,310,354	6

* Some vehicles equipped with systems using HFO-1234yf, a low-GWP refrigerant.

Table 3-14. Reported A/C Efficiency Credits by Manufacturer and Fleet, 2015 Model Year (Mg)

Manufacturer	Car	Truck	Total	Grams/Mile Equivalent of Total Credits
BMW	274,938	84,627	359,565	4
FCA	673,129	1,507,070	2,180,199	5
Ford	488,390	678,740	1,167,130	3
GM	874,646	1,502,958	2,377,604	4
Honda	292,252	268,813	561,065	2
Hyundai	391,740	35,125	426,865	3
Jaguar Land Rover	15,515	69,278	84,793	6
Kia	400,117	37,797	437,914	3
Mercedes	247,753	151,042	398,795	5
Nissan	717,255	229,139	946,394	3
Subaru	89,553	242,945	332,498	2
Tesla	27,071		27,071	6
Toyota	1,246,673	926,150	2,172,823	4
Volkswagen	383,978	129,509	513,487	4
Volvo	21,613	7,679	29,292	2
Fleet Total	6,144,623	5,870,872	12,015,495	3

MY2015 Incentives: 0 g/mile Upstream Emissions

Source: US EPA, "Manufacturer Performance Report for the 2015 Model Year" EPA 420 R 16 014, November 2016

Table 3-4. Production Volumes of Advanced Technology Vehicles Using Zero Grams/Mile Incentive, by Model Year

Manufacturer	2010	2011	2012	2013	2014	2015	Total
BMW	-	-	-	-	9,895	11,386	21,281
BYD Motors	-	-	11	32	50	-	93
Coda	-	-	-	37	-	-	37
FCA	-	-	-	2,353	3,404	7,825	13,582
Fisker	-	-	1,415	-	-	-	1,415
Ford	-	-	653	18,654	18,826	17,384	55,517
GM	-	4,370	18,355	27,484	25,847	14,847	90,903
Honda	-	-	-	471	1,635		2,106
Hyundai						72	72
Kia	-	-	-	-	-	926	926
McLaren	-	-	-	-	43	N/A	43
Mercedes	-	546	25	880	3,610	3,125	8,186
Mitsubishi	-	-	1,435	-	219	-	1,654
Nissan	-	8,495	11,460	26,167	10,339	33,242	89,703
Tesla	599	269	2,952	17,813	17,791	24,322	63,746
Toyota	-	-	452	829	1,218	-	8,337
Volkswagen	-	-	-	-	755	4,869	5,624
Total	599	13,680	36,306	93,891	91,659	113,129	349,264

2025 CO2 Standard is a Function of Car & Truck Production Volume and Vehicle Footprint

Passenger Car Target (g/mi) = (3.26 x **footprint**) – 3.2

- for vehicle footprints >41 and < 56 square feet

Light-Truck Target (g/mi) = (3.58 x **footprint**) +12.5

- for vehicle footprints >41 and < 74 square feet

For each individual company the Car & Truck standards are a function of the # **vehicles produced** & each vehicle's **footprint**

Advanced Technology Incentives

Incentives for full-size pickup trucks using hybrid or other clean technology

- Per-vehicle credit for hybrid full-size pick-up trucks produced at minimum penetration rates
  - Mild hybrid: 10 g/mi from 2017-2021 (minimum penetration is 20% of full-size pick-up sales in 2017, increases to 80% by 2021)
  - Strong hybrid: 20 g/mi from 2017-2025 (minimum penetration is 10% of full-size pick-up sales)
- Performance-based incentive credit for exceeding target by 15-20%

Advanced technology vehicle multipliers

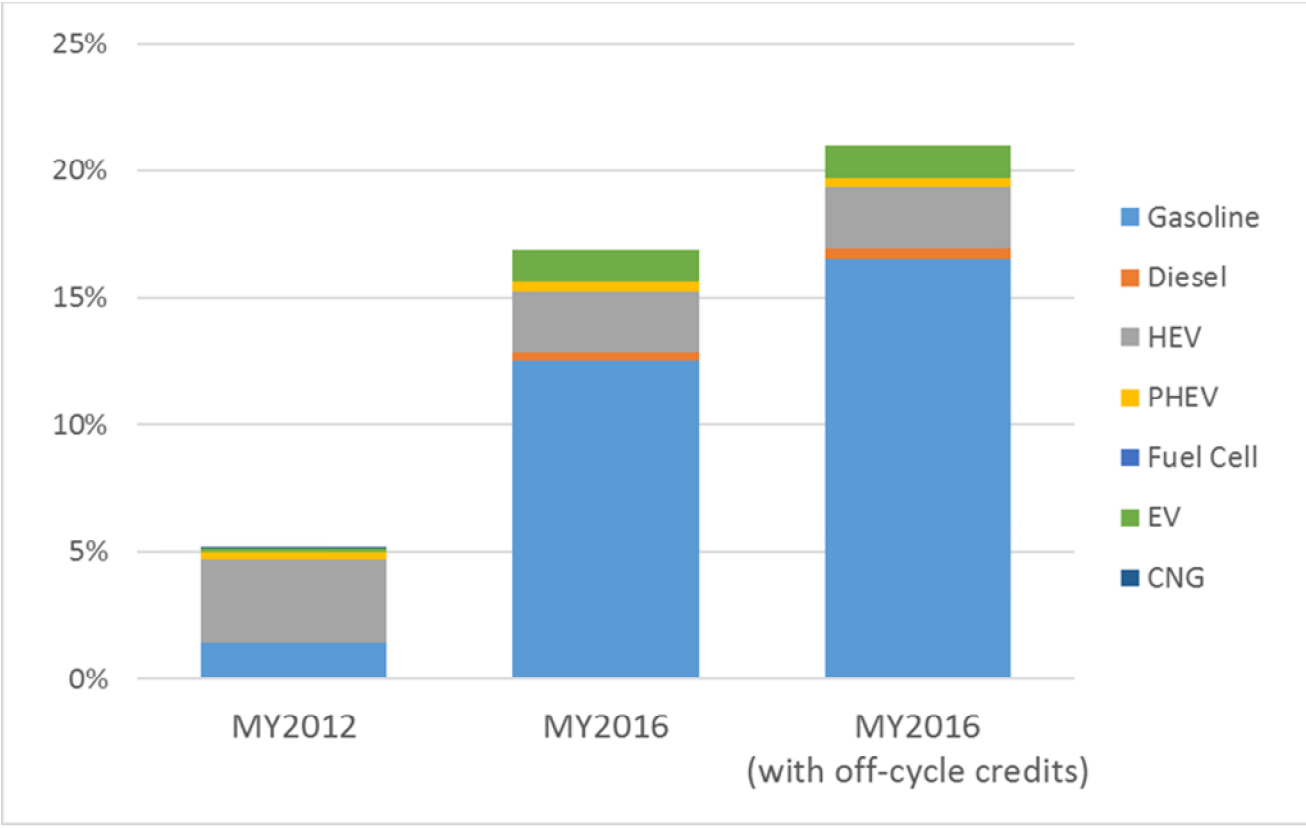
- Applies to electric, plug-in hybrid electric, fuel cell, and compressed natural gas vehicles
  - EVs/FCVs: 2.0 in MY2017 phasing down to 1.5 in MY2021
  - PHEVs/CNGs: 1.6 in MY2017 phasing down to 1.3 in MY2021
- Multiplier allows manufacturers to count vehicles more than once in CO_2 fleet average calculation
- No multipliers for MY2022 and beyond

Upstream emissions for electric vehicles (EVs)

- For MYs 2017-2021: EVs/PHEVs/FCVs count as 0 g/mile in compliance calculation with no vehicle sales limits
- For MYs 2022-2025, 0 g/mile treatment allowed up to a per-company cumulative sales cap:
  - 600,000 for companies that sell 300,000 EV/PHEV/FCVs in 2019-2021
  - 200,000 for other companies
- Upstream emissions are fully counted in GHG impacts of the program

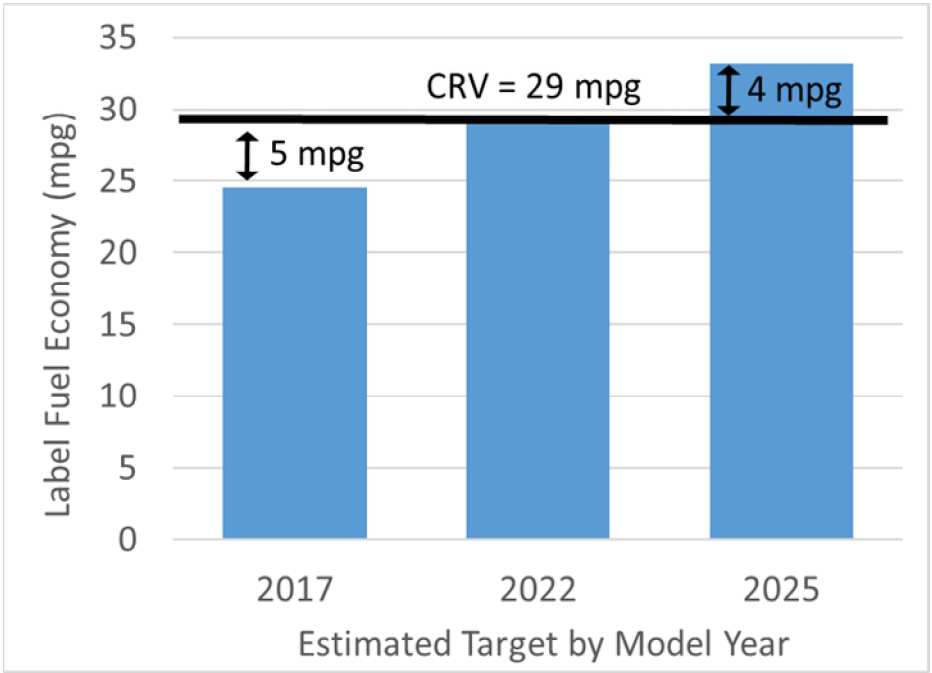
Advanced Gasoline Vehicles can Take the Industry Much Further …
many vehicles already meet future targets

Vehicle Production that Meets or Exceeds MY2020 CO_2 Targets



With fleet averaging, in any given model year, only about 50% of vehicles would need to meet/exceed their target, depending on sales volumes.

Case Study: 2017 Honda CRV 1.5 liter AWD



- Best-selling SUV in U.S.
- AWD versions make up 2/3 of sales
- Advanced Gasoline Technology:
  - Turbocharged GDI 1.5 liter I4 engine
  - Continuously variable transmission
  - No electrification
- Could already meet* 2022 target
  - 5 years ahead
- Within 4 mpg of 2025 target
  - ➢ *With 8 years to go*

**Illustrative example only. EPA estimated real-world fuel economy targets from CO_2 compliance targets, assuming A/C credits and 5 g/mi off-cycle credits*