EPA'S ASSESSMENT FOR THE MIDTERM EVALUATION

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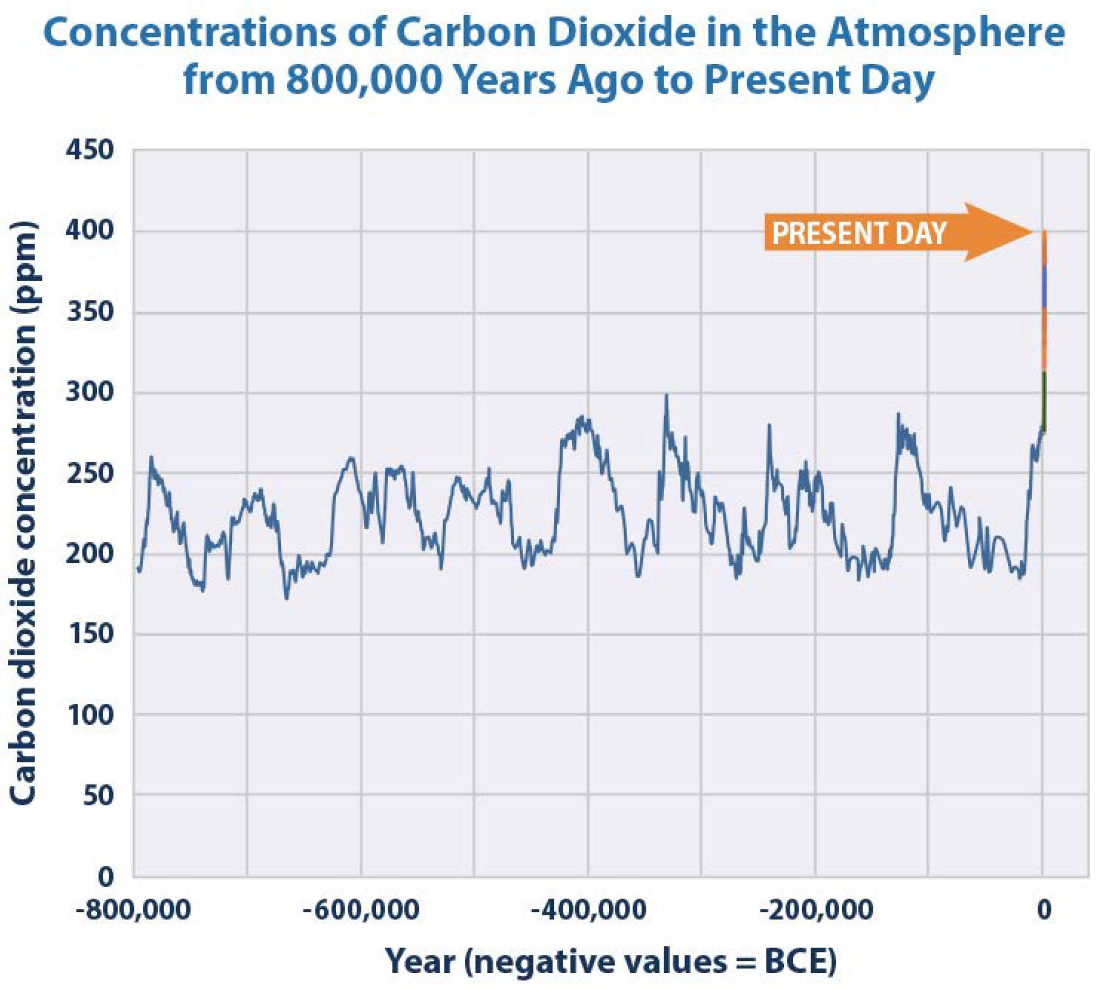
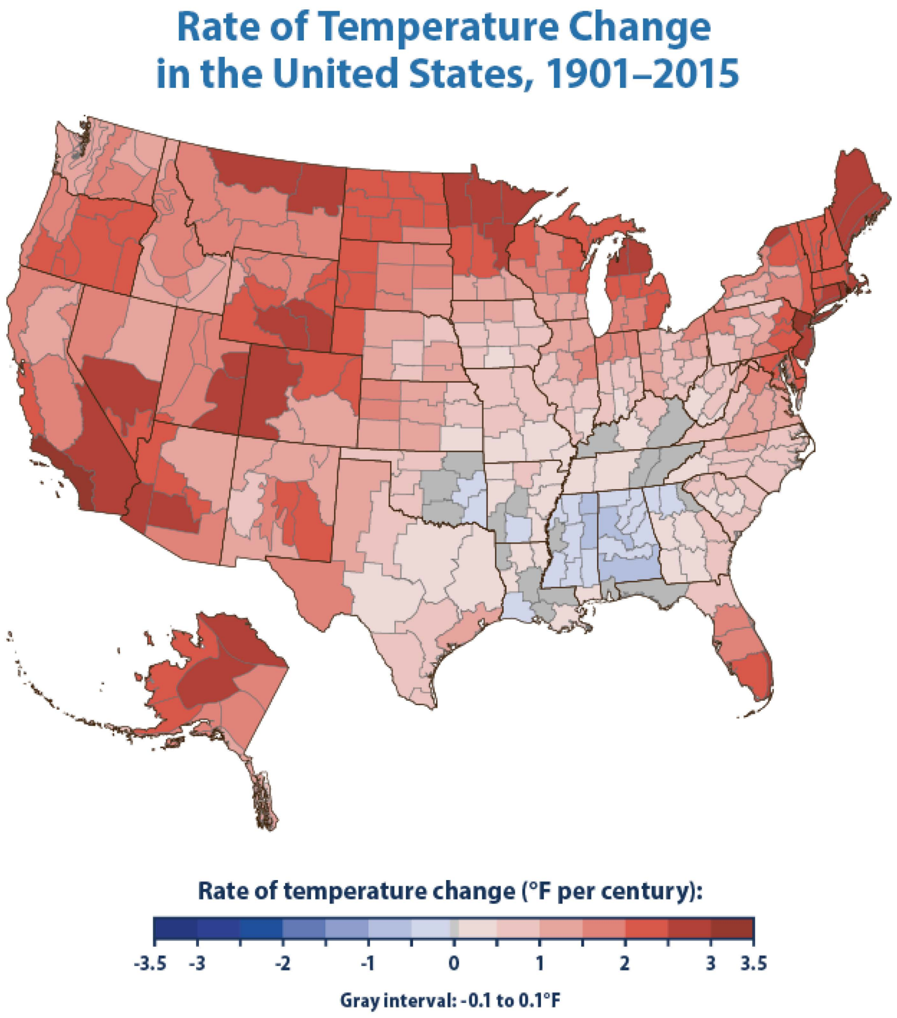
Overview

- **Climate Change**
- **Greenhouse Gas Regulations**
- **MTE Results**
  - Powertrain
  - Load reduction
  - Consistency in Findings
  - Electrification
- **Conclusion**

Climate Indicators: CO2 Concentration & Average U.S. Temperatures

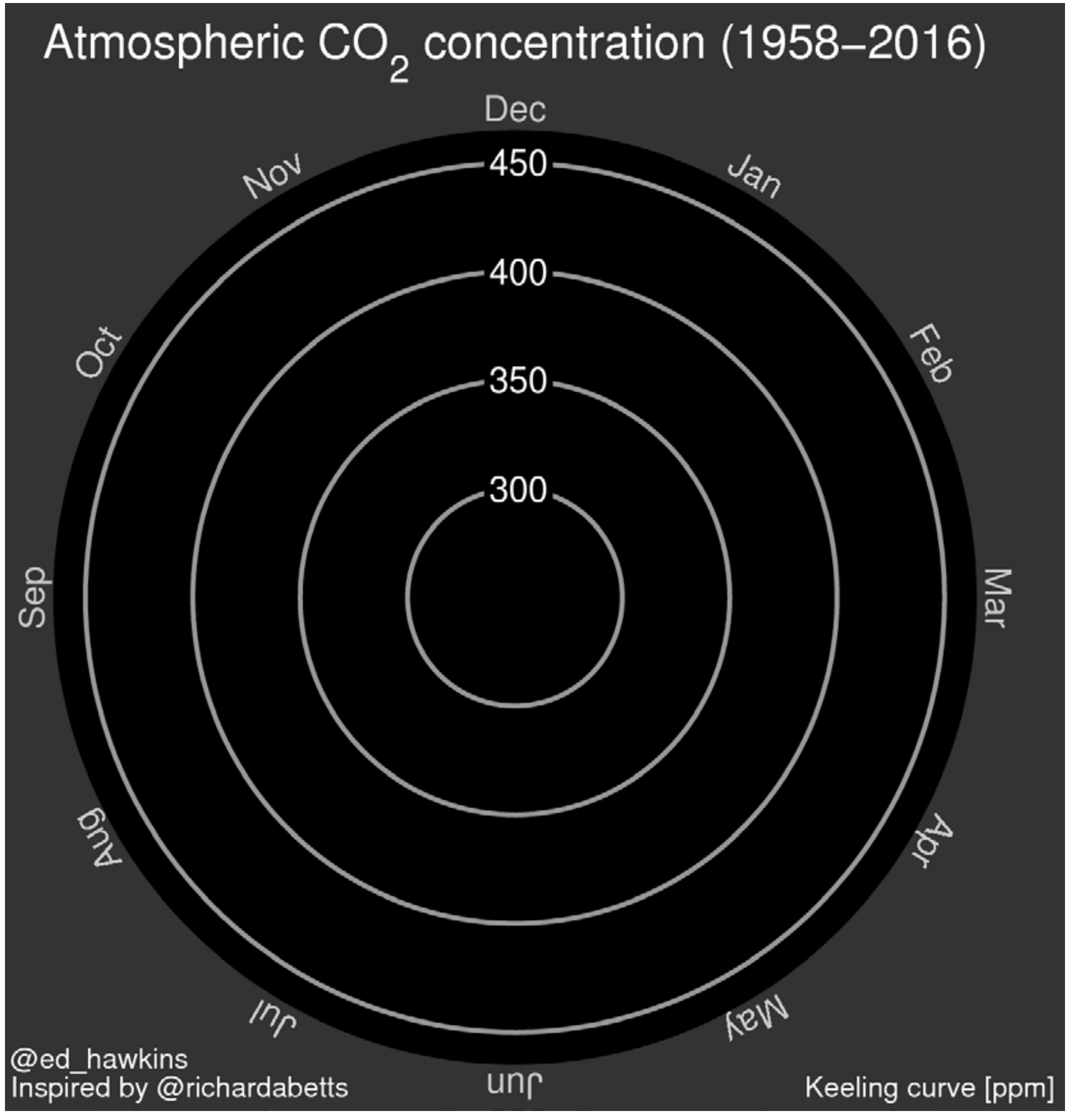


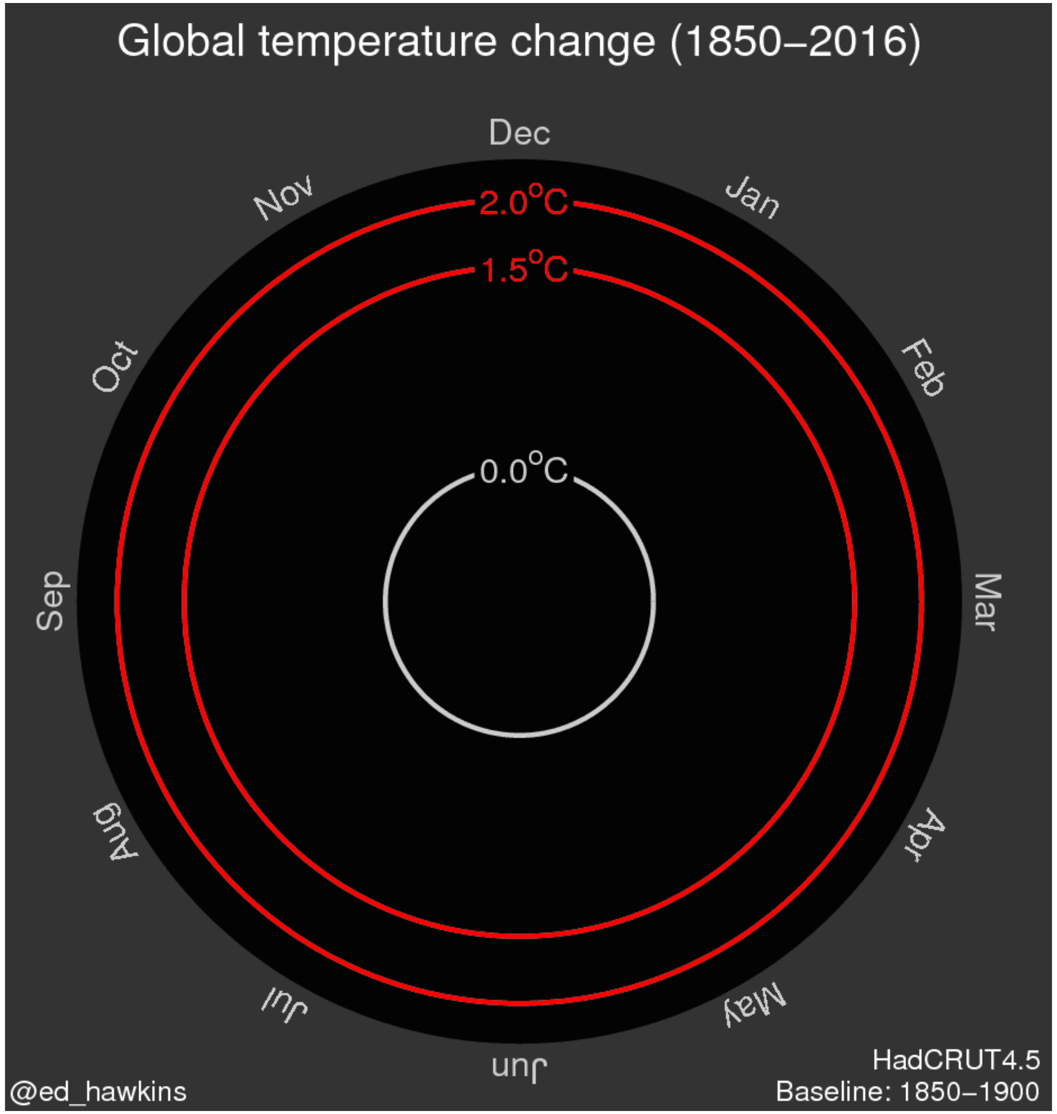
Data source: Compilation of 10 underlying datasets.



Data source: NOAA, 2016

Climate Indicators: CO2 Concentration (58 years) **& Global Temperatures** (166 years)





source: http://www.climate-lab-book.ac.uk/spirals/ (accessed 1/17/2017)

Light-duty Vehicle Greenhouse Gas Emission Reductions
Multiple Analyses and Rulemakings Conducted Over the Last 9 years

EPA/NHTSA NPRM
September, 2009

EPA/NHTSA NPRM
December, 2011

EPA/NHTSA/CARB DTAR
July, 2016

EPA FD
January, 2017

EPA Staff Report
March, 2008

EPA/NHTSA FRM
May, 2010

EPA/NHTSA FRM
October, 2012

EPA PD
December, 2016

EPA's MTE assessments informed by a wide range of information

- **Technical research initiated by EPA**
  - Benchmarking testing of 30 vehicles across wide range of powertrains & segments
  - 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

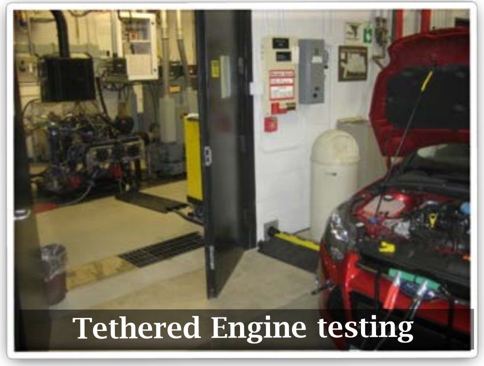
EPA has shared technical information publicly throughout MTE Process

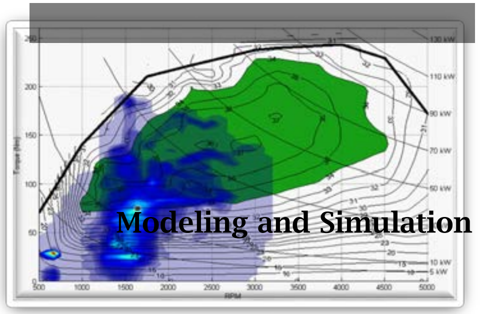

EPA's National Vehicle and Fuel Emissions Laboratory
Ann Arbor, MI

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

Final Determination Conclusions

- Compliance can be achieved through a number of different technology pathways reflecting predominantly the application of technologies already in commercial production.

- EPA projects that the MY 2022~2025 standards can be met through advances in gasoline vehicle technologies, such as engines, transmissions, light-weighting, aerodynamics, and accessories.

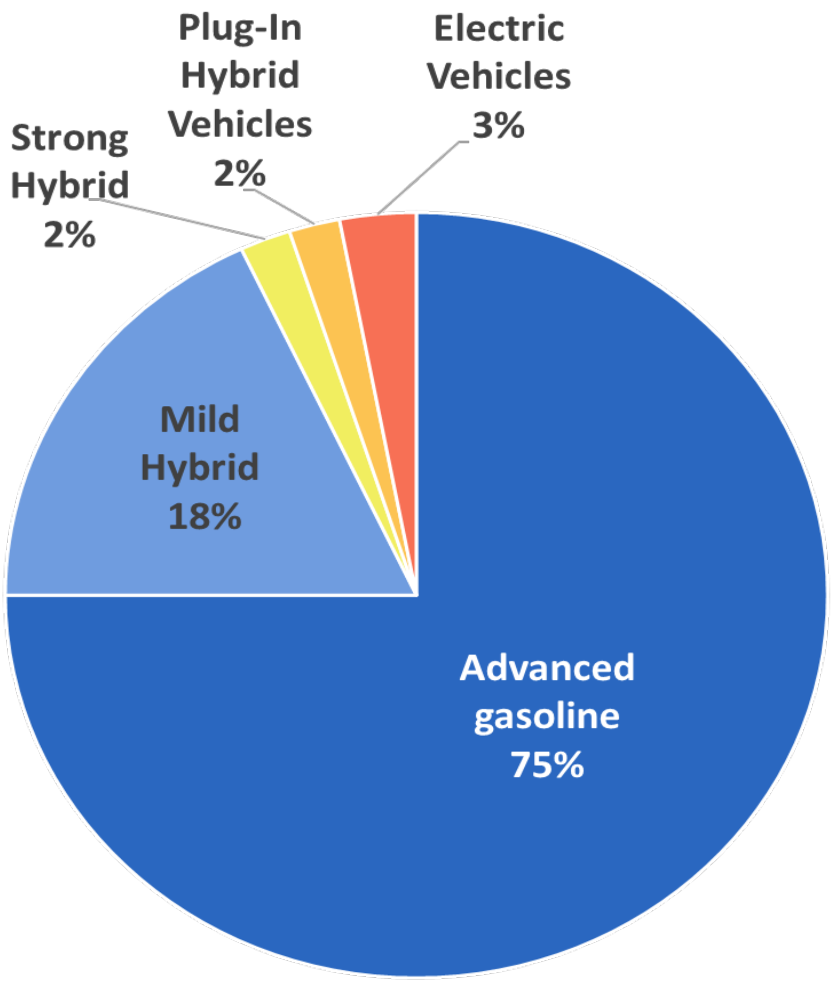
- Very low levels of strong hybrids and electric vehicles will be needed to meet the standards.

- Standards provide significant benefits to consumers and public

Standards can be met mostly with advanced gasoline technologies

- 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)

One possible pathway EPA modeled



If the conclusions are the same, what has changed?

- **Fuel prices have dropped and people are buying more trucks than cars.**
  - Achieved CO2 is projected to be 173 g/mi in 2025 MY vs 163 g/mi projected in the FRM

Attribute	2012 Final Rule	Draft TAR	Proposed Determination		
	AEO 2011 Reference	AEO 2015 Reference	AEO 2016 Reference	AEO 2016 Low	AEO 2016 High
Car/Truck Mix	67/33%	52/48%	53/47%	44/56%	63/37%
CO_2 (g/mi)	163	175	173	178	167

- **Manufacturers have complied with the first 4 years of the 2012~2016 MY program. (2016 MY results have not yet been tabulated.)**
  - And, for the first time in automotive history, experienced 6 consecutive years of increasing sales
- **Manufacturers have introduced technologies that we did not anticipate in the 2012 FRM**
  - Atkinson Cycle engines in non-hybrid applications
  - Turbo-downsized engines already performing at levels projected for 2020 MY.
  - Continuously Variable Transmissions (CVT) that feel like conventional automatics
  - 48 volt Mild Hybrids

MTE Results: MY 2025 Fleet Projections

Selected Technology Penetrations (Absolute) and Per-Vehicle Average Costs*
to Meet MY2025 Standards

Technology	Draft TAR	Proposed Determination	
		Primary Analysis	Range of Sensitivities Analyzed
Turbocharged and downsized engines	33%	34%	31~41%
Higher compression ratio, naturally aspirated gasoline engines	44%	27%	5~41%
8-speed and other advanced transmissions	90%	93%	92~94%
Mass reduction	7%	9%	2~10%
Off-cycle technology	Not modeled	26%	13~52%
Stop-start	20%	15%	12~39%
Mild Hybrid	18%	18%	16~27%
Strong Hybrid	<3%	2%	2~3%
Plug-in Hybrid electric vehicle	<2%	2%	2%
Electric vehicle	<3%	3%	2~4%
Per vehicle cost (2015$)	$920	$875	$800~$1,115

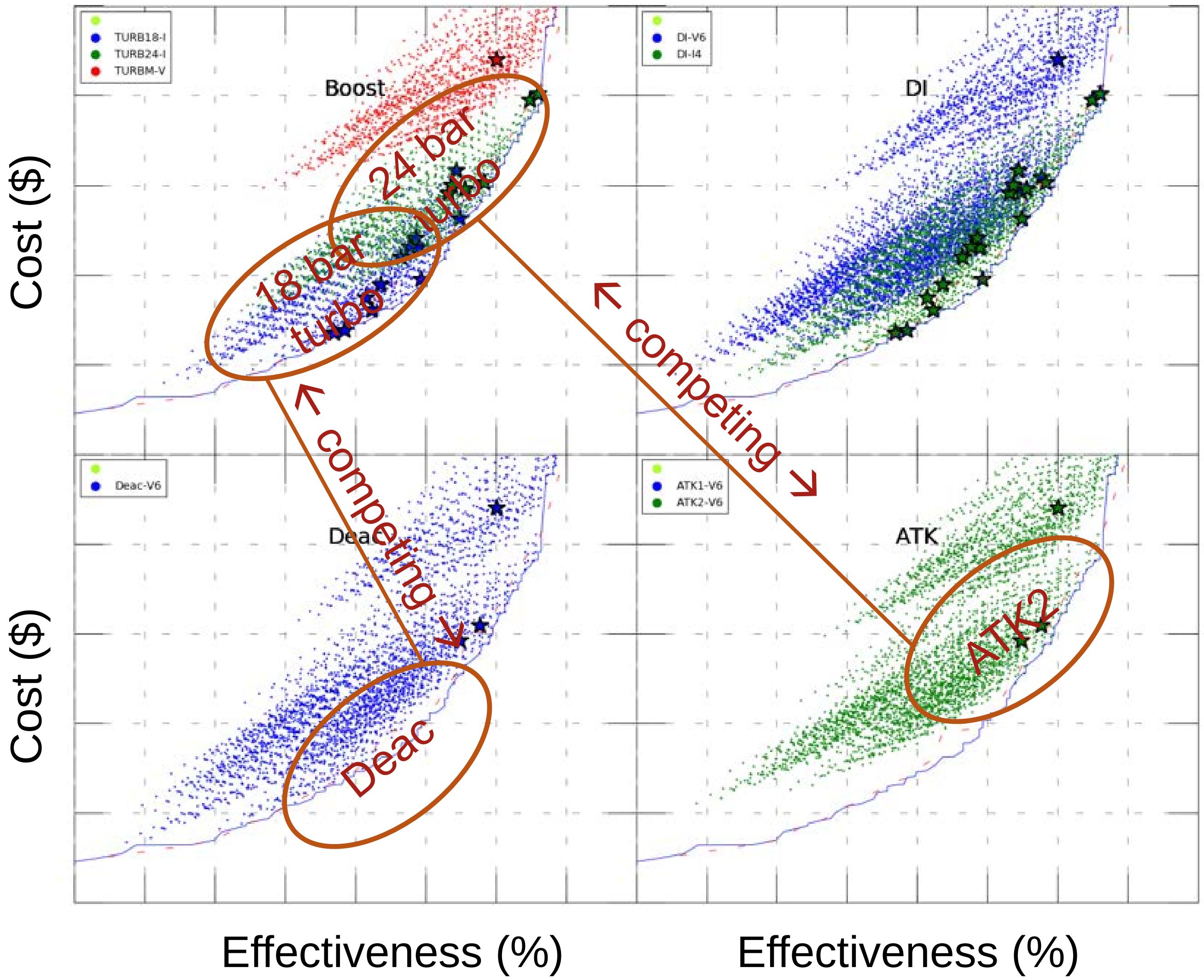
* Incremental to the Costs to Meet the MY2021 Standards

Example of Competing Technologies: Engines

Manufacturers have multiple cost-effective options for compliance

Engine Example:

- **Different engine technologies compete for the frontier of cost-effective options**
  - Turbocharging and downsizing
  - Atkinson Cycle/ Deac
- **Small changes in package cost and/or effectiveness can result in one or the other technology being applied**
  - However, overall costs remain very stable
- **Manufacturers will choose which technology best fits their product applications**



Example of Competing Technologies: Transmissions

Similar alternatives exist for vehicle manufacturers regarding the selection of transmission technologies

Manufacturers are predominantly applying three current primary transmission architectures:

- Conventional automatic transmissions
- Continuously variable transmissions
- Dual clutch transmission

All three transmission types are driving towards the same goal of providing maximum flexibility to operate the engine and maximum transmission efficiency.

Once again, vehicle manufacturers will select the transmission architecture that best fits its product portfolio.

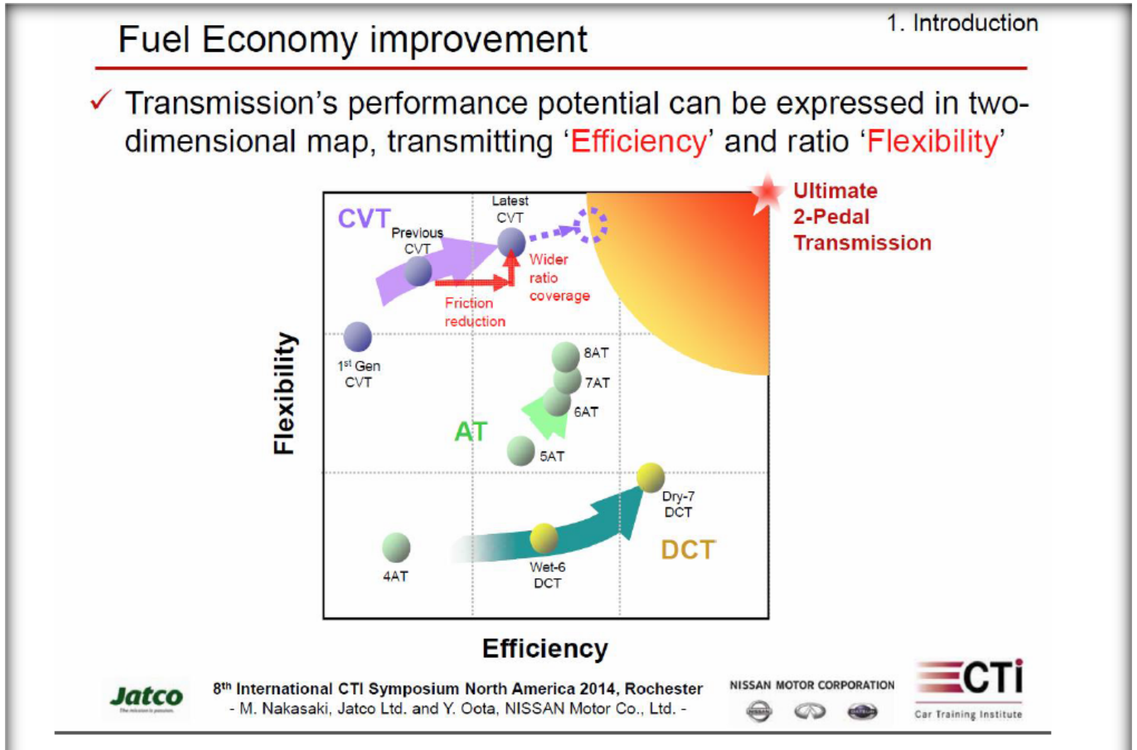
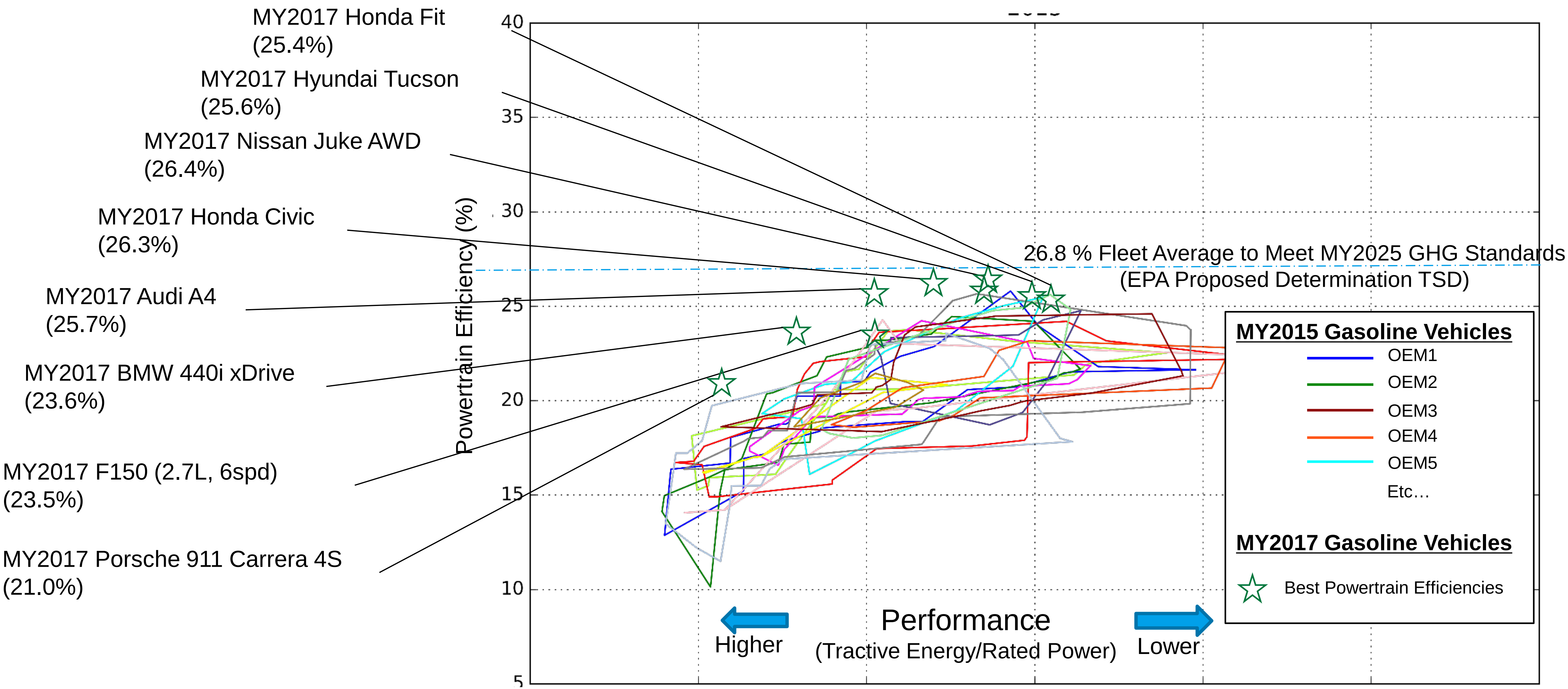


Figure 2.116 Comparison of the Different Transmission Types

Powertrain Efficiency: Current Levels and Projected Improvement Needed



Progress in Engine Efficiency

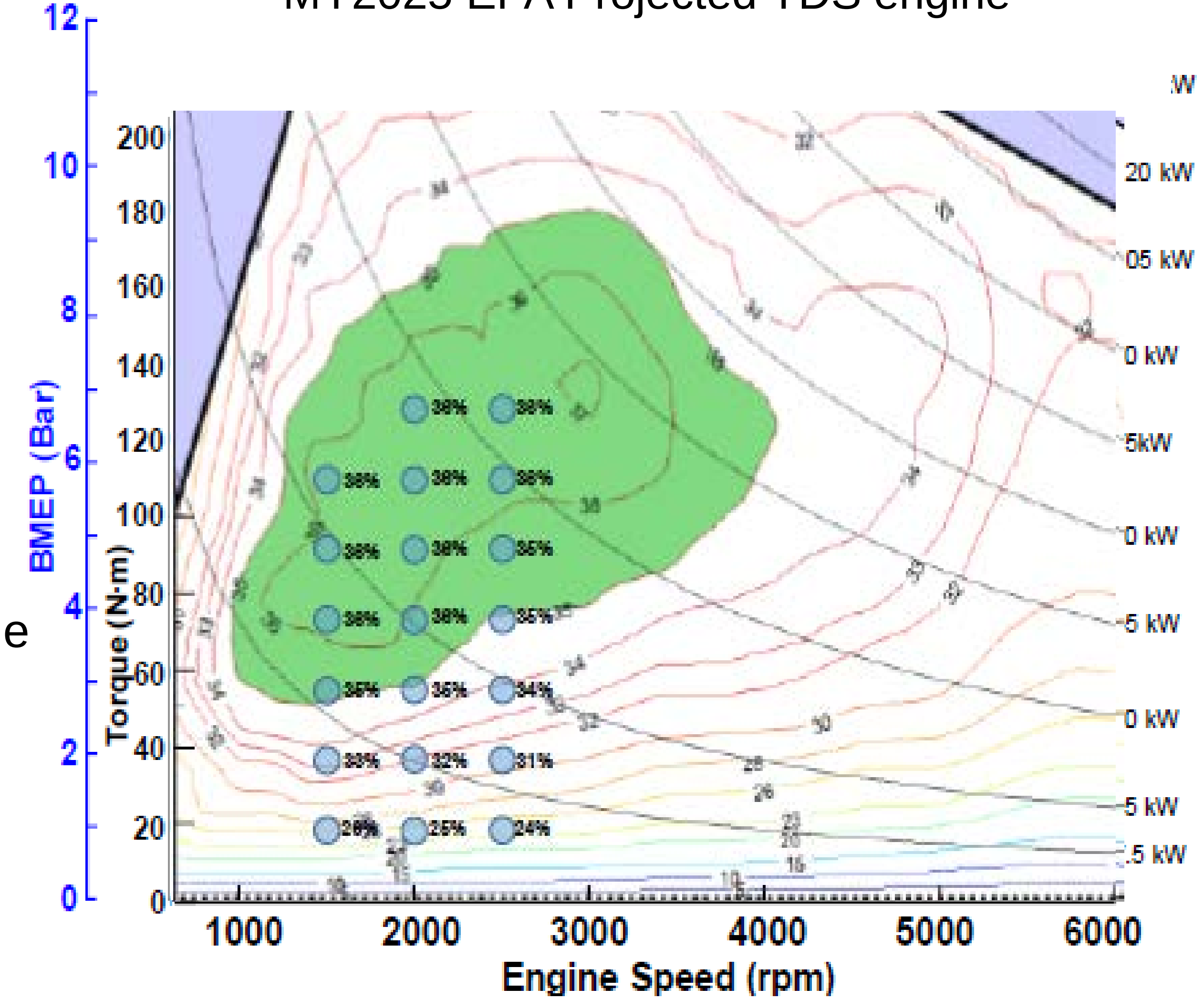
MY2008 Actual PFI Engine
- Peak thermal efficiency 34%
- Narrow efficiency region

MY2014 Actual GDI Engine
- Peak thermal efficiency 36%
- Broader efficiency region

MY2016 Actual Turbo downsized Engine
- Peak thermal efficiency 38%
- Very broad efficiency region
- Large overlap with 2-cycle test operation

MY2025 EPA projected turbo downsized engine
- Peak thermal efficiency 38%
- Similar efficiency region as MY2016 actual engine
- Hardware improvements provide some improved low-load efficiency

MY2025 EPA Projected TDS engine



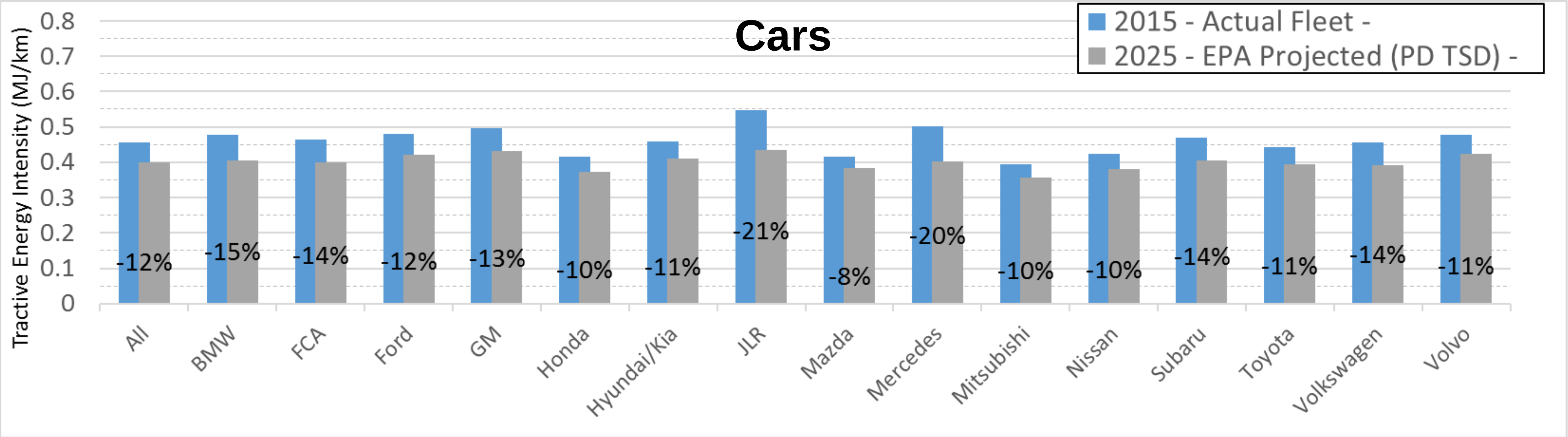
Load Reduction: Projected Improvement to Meet 2025 Standards

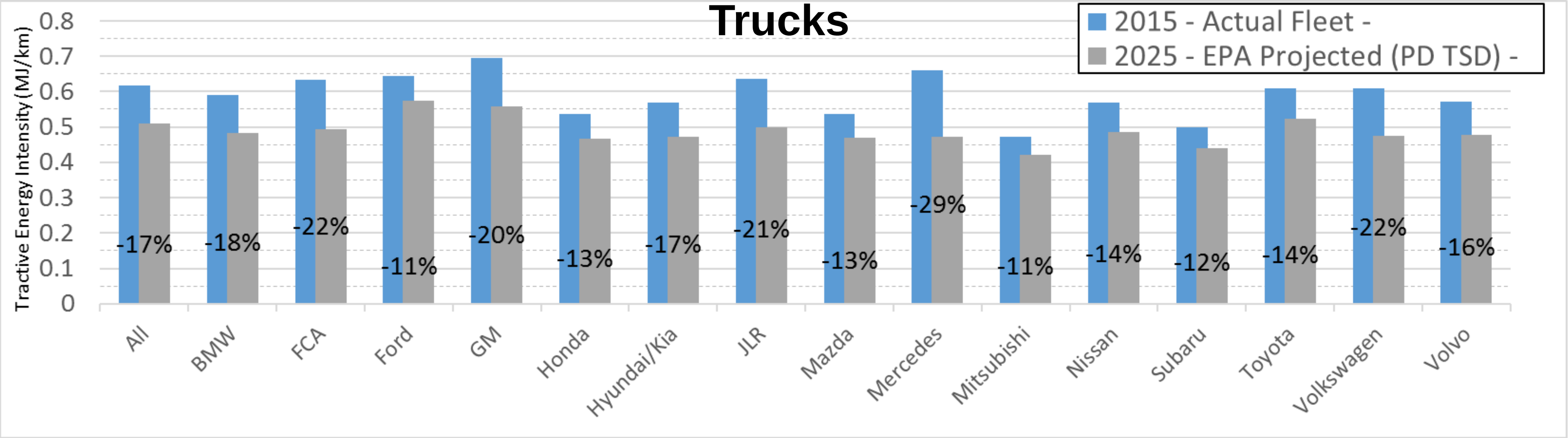
Improving powertrain efficiency is one half of the solution to improve overall vehicle efficiency

Managing road loads (the amount of energy required to move a vehicle down the road) is also important.

Road load reductions

- **Lower vehicle mass**
- **Aerodynamic improvements**
- **Lower rolling resistance tires**





Sensitivities

EPA conducted a range of sensitivity analyses to evaluate the effects of individual program elements on the overall results

Despite the application of unlikely assumptions (i.e. no additional mass reduction) the overall average cost of compliance remained stable

Table C.34 MY2025 Absolute Technology Penetrations & Incremental Costs for the Fleet in Each OMEGA Run (2015$)

Tech	AEO Ref (Central Case)	AEO High	AEO Low	Perfect Trading	No C/T Transfers	No additional MR	Non-ATK2 Path	Non-TRX22 Path	RPE
VVT	95%	94%	96%	96%	95%	95%	95%	94%	96%
VVLT	31%	27%	32%	30%	25%	27%	38%	30%	24%
Deac	49%	51%	46%	50%	51%	52%	43%	50%	55%
TRX11	0%	0%	0%	0%	0%	0%	0%	0%	0%
TRX21	5%	3%	6%	2%	7%	2%	3%	92%	8%
TRX22	88%	90%	88%	92%	86%	90%	91%	0%	86%
TDS18	27%	24%	28%	41%	24%	27%	26%	27%	26%
TDS24	7%	7%	7%	0%	9%	10%	13%	12%	6%
ATK2	27%	31%	24%	34%	33%	41%	5%	38%	27%
CEGR	35%	39%	32%	33%	41%	49%	21%	48%	34%
Miller	2%	1%	2%	0%	2%	5%	0%	3%	2%
Stop-Start	15%	18%	12%	21%	17%	19%	20%	39%	19%
Mild HEV	18%	16%	20%	16%	16%	27%	26%	18%	22%
Full HEV	2%	3%	2%	2%	2%	3%	2%	3%	3%
PHEV	2%	2%	2%	2%	2%	2%	2%	2%	2%
BEV	3%	4%	3%	2%	3%	4%	3%	4%	3%
OC1	12%	13%	11%	13%	30%	24%	21%	30%	8%
OC2	14%	14%	14%	0%	15%	23%	20%	21%	14%
WR tech	9%	9%	9%	8%	9%	2%	10%	10%	8%
WR net	8%	8%	8%	7%	8%	1%	8%	9%	7%
$/veh	$875	$882	$886	$843	$880	$797	$920	$1,115	$1,038
Delta $/veh	$0	$7	$11	-$32	$5	-$78	$45	$240	$163

What about vehicle electrification?

- **The MTE analysis projects very little electrification will be required to meet the 2025 MY standards, however, for those manufacturers that choose to sell electrified vehicles they can make a major contribution.**
- **2025 MY standards were set based largely on improvements in gasoline vehicle performance, and only small levels of electrification**
  - Had the standards been set based on high penetrations of electrification technology, they would need to be much more stringent

This table <u>does not include EV’s</u> which perform even better with respect to future standards

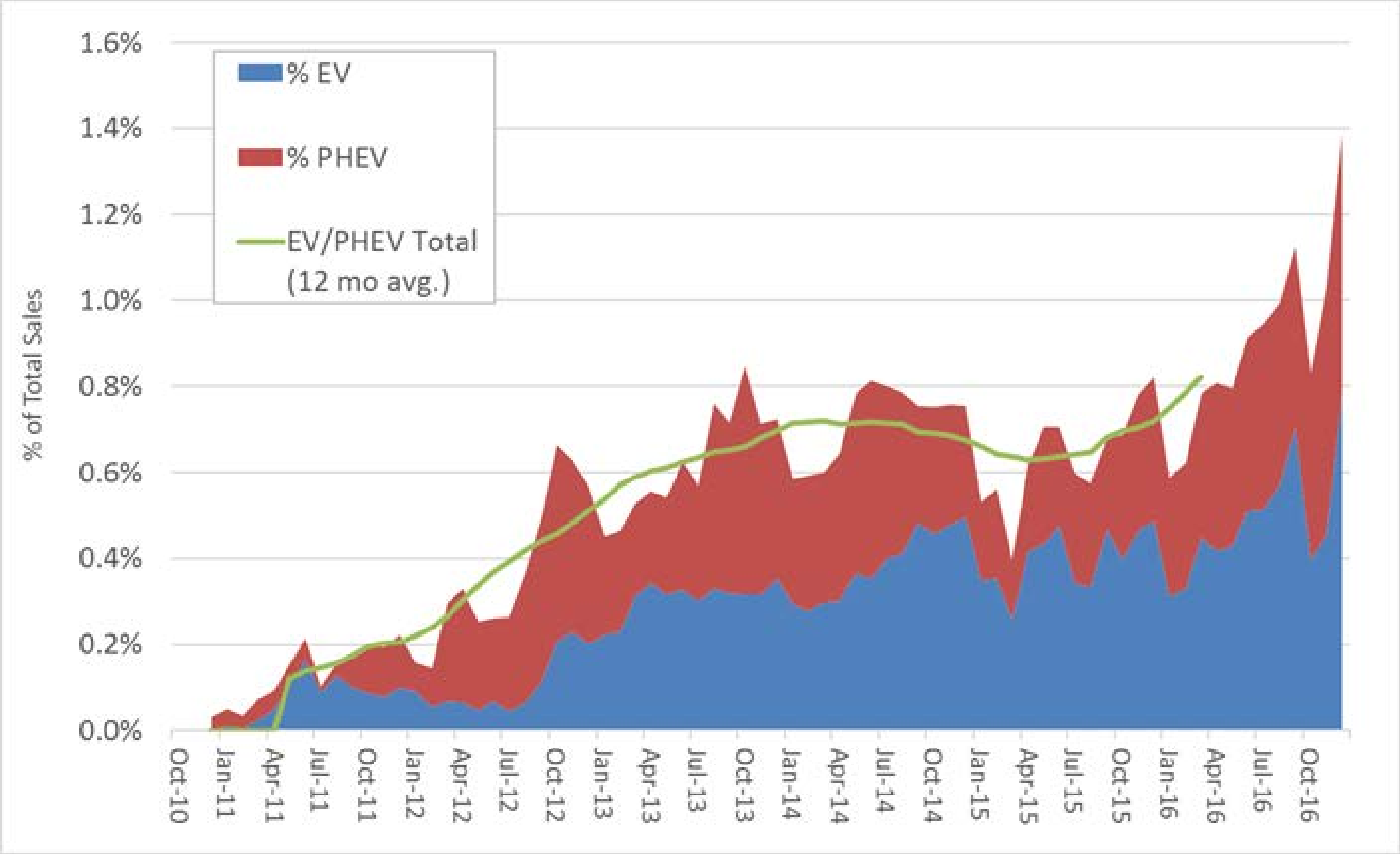
Model Year	Manufacturer	Vehicle	Fuel Economy (mpg)	Tailpipe CO_2 (g/mile)	Footprint (ft^2)	Powertrain Type	Trans-mission	Engine Disp. (L)	Vehicle Class	Car/ Truck	Compliance 2017	2018	2019	2020	2021	2022	2023	2024	2025
2016	BMW	I3 REX	132.2	23	43.5	PHEV	A1	0.6	Subcompact Cars	C	95%	96%	96%	97%	97%	97%	[illegible]	[illegible]	[illegible]
2016	Chevrolet	Volt	115.6	30	46.2	PHEV	AV	1.5	Compact Cars	C	92%	92%	93%	93%	94%	93%	[illegible]	[illegible]	92%
2016	Cadillac	ELR	82.8	54	45.9	PHEV	AV	1.4	Subcompact Cars	C	81%	81%	80%	80%	80%	79%	78%	77%	[illegible]
2016	Toyota	Prius Eco	80.8	110	44.6	HEV	AV	1.8	Midsize Cars	C	81%	81%	80%	80%	80%	79%	78%	77%	[illegible]
2016	Cadillac	ELR Sport	82.8	54	45.9	PHEV	AV	1.4	Subcompact Cars	C	81%	81%	80%	80%	80%	79%	78%	77%	[illegible]
2016	Hyundai	Sonata	87.5	64	48.3	PHEV	AM6	2.0	Midsize Cars	C	78%	77%	77%	76%	76%	74%	73%	72%	[illegible]
2016	Ford	Fusion	74.8	86	48.7	PHEV	AV	2.0	Midsize Cars	C	68%	67%	66%	65%	64%	62%	61%	59%	[illegible]
2016	Ford	C-MAX	74.8	86	43.8	PHEV	AV	2.0	Midsize Cars	C	65%	64%	62%	61%	60%	58%	56%	54%	[illegible]
2016	Audi	A3 e-tron ultra	64.3	90	43.7	PHEV	AM-S6	1.4	Compact Cars	C	63%	62%	60%	59%	57%	56%	53%	51%	[illegible]
2016	Audi	A3 e-tron	64.3	105	43.7	PHEV	AM-S6	1.4	Compact Cars	C	55%	54%	52%	51%	49%	46%	44%	41%	[illegible]
2016	BMW	I8	56.6	125	48.5	PHEV	A6	1.5	Subcompact Cars	C	51%	49%	47%	45%	43%	40%	38%	35%	[illegible]
2016	Volvo	XC90 AWD	42.4	166	53.5	PHEV	S8	2.0	Sport Utility Vehicles	T	48%	48%	48%	47%	43%	40%	37%	34%	[illegible]
2016	Toyota	Prius	74.0	120	44.6	HEV	AV	1.8	Midsize Cars	C	49%	47%	45%	43%	41%	38%	35%	32%	[illegible]
2016	BMW	X5 xDrive40e	42.6	169	52.0	PHEV	S8	2.0	Sport Utility Vehicles	T	46%	46%	45%	44%	40%	37%	34%	31%	[illegible]
2016	BMW	330e	55.0	128	46.9	PHEV	S8	2.0	Compact Cars	C	48%	46%	44%	42%	39%	37%	34%	30%	[illegible]
2016	Porsche	Cayenne S e-Hybrid	37.5	183	51.8	PHEV	AM8	3.0	Sport Utility Vehicles	T	41%	41%	40%	39%	34%	31%	27%	24%	[illegible]
2016	Chevrolet	Malibu	61.5	145	48.4	HEV	AV	1.8	Midsize Cars	C	42%	40%	37%	35%	32%	29%	26%	22%	[illegible]
2016	Toyota	Prius c	70.8	126	40.6	HEV	AV	1.5	Compact Cars	C	42%	40%	37%	35%	32%	29%	26%	22%	[illegible]
2016	Ford	Fusion Hybrid	59.6	149	48.4	HEV	AV	2.0	Midsize Cars	C	40%	38%	35%	33%	30%	27%	23%	20%	[illegible]
2016	Lincoln	MKZ Hybrid	59.6	149	48.4	HEV	AV	2.0	Midsize Cars	C	40%	38%	35%	33%	30%	27%	[illegible]	[illegible]	[illegible]
2016	Porsche	Panamera S E-Hybrid	43.8	161	52.2	PHEV	AM-S8	3.0	Large Cars	C	40%	37%	35%	32%	29%	26%	[illegible]	[illegible]	[illegible]
2016	Hyundai	Sonata Hybrid SE	58.1	153	48.0	HEV	AM6	2.0	Midsize Cars	C	38%	36%	33%	30%	27%	24%	[illegible]	[illegible]	[illegible]

97%

13%

EV and PHEV Sales

- PHEVs set new sales records in 2016, with EV sales up 25% over last year, and PHEVs up around 70%.
- The fourth quarter was a record quarter for PHEVs, and the second best quarter ever for EVs (second only to last quarter).
- December, 2016 was a record sales month for both EVs and PHEVs
- EVs have now outsold PHEVs for 10 straight quarters
    - For the first time in over 2 years PHEVs did outsell EVs in an individual month.



Conclusion

EPA has projected that the future fleet will look and operate much the same as it does today …. But with more technology that improves vehicle efficiency:

- **Gasoline engine with smaller displacement and possibly turbocharged**
  - Operating in Atkinson or Miller Cycle
- **Higher number of gears in a more efficient transmission**
  - or be equipped with an advanced CVT or DCT
- **Lower weight**
- **Better Aerodynamics**
- **Lower rolling resistance tires**
- **Mild electrification**

Thank you!

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