THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

How things work: OMEGA modeling case study based on the 2018 Toyota Camry

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The 2018 Toyota Camry incorporates eight technology upgrades that are specifically modelled in the U.S. Environmental Protection Agency's Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) and Lumped Parameter Model (LPM). This large number of simultaneous technology upgrades makes the Camry an excellent case study of how accurately the EPA's models project future technology benefits and handle synergies between technologies.

This paper carries out that case study. It defines and adjusts for all differences between the 2015 and 2018 Camry and all differences between the EPA's technology assumptions and technology on the 2018 Camry. The results show that the actual CO_2 reductions of 18.6% achieved in the 2018 Camry exceed the 17.7% reductions predicted by EPA models. This confirms that the OMEGA and LPM models accurately predict both new technology benefits and synergies between technologies. If anything, they are somewhat conservative. It also suggests that other studies contradicting EPA model outcomes, including specifically a study commissioned by the largest vehicle manufacturer association and performed by Novation Analytics, are inaccurate and underpredict future technology benefits.

Background

Modeling efficiency technology is complicated and difficult as there are synergies and overlaps between technologies. The efficiency impact of any technology varies depending on what other technologies are bundled with it, the order in which the model adds technologies to a vehicle, and the characteristics of the vehicle. The importance of accurately modeling these synergies has been widely acknowledged and promoted. For example, the 2015 National Academy of Sciences study on CAFE stated:

> Further, the committee notes that the use of full vehicle simulation modeling in combination with lumped parameter modeling and teardown studies contributed substantially to the value of the Agencies' estimates of fuel consumption and costs, and it recommends they continue to increase the use of these methods to improve their analysis. The committee recognizes that such methods are expensive but believes that the added cost is well justified because it produces more reliable assessments (Recommendation 8.3).[1]

As noted by the National Academy of Sciences committee, the agencies have developed sophisticated computer simulation models to address technology synergies. The EPA has developed its own full-vehicle computer simulation model, ALPHA, to estimate the effects of individual technologies and technology packages. The ALPHA data and outputs are used to calibrate the EPA's Lumped Parameter Model (LPM), which is used to account for synergies between technologies. Finally, the EPA's OMEGA model is used to assign the technology results and synergies to 29 vehicle classes and to assess the cost of compliance

1 Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, Phase 2, *Cost, effectiveness and deployment of fuel economy technologies for light-duty vehicles* (2015). https://www.nap.edu/read/21744/chapter/1#vii.

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with standards. The LPM is built into the various OMEGA modeling runs.[2]

The issue

Based on a study by Novation Analytics,[3] the Alliance of Automobile Manufacturers (AAM) asserted in comments on the Reconsideration of EPA's Final Determination that there was systematic bias in the LPM:[4]

The AAM highlights the following issues identified by the study for EPA's attention for reconsideration of the Prior Determination.

- The addition of power-to-weight and vehicle road load does little to improve the accuracy of the LPM.
- LPM-informed OMEGA technology packages for the Prior Determination continue to fail reasonable tests for plausibility. Notwithstanding EPA comments to the contrary, the Alliance believes that the plausibility limits chosen remain appropriate.
- Only 18% of the Prior Determination's technology packages are traceable to the ALPHA full vehicle simulations through the LPM. The underlying data for other LPM-based assessments is unclear.
- The LPM-based technology package simulations appear to have a high-efficiency, low-CO_2 bias, on average as compared to the underlying ALPHA data.

In a meeting with the AAM on November 8, 2017, the EPA directly addressed the LPM modeling issues raised by the AAM.[5] However, this report takes a different approach. Rather than argue about the merits of individual pieces of the modeling procedure, this report conducts a case study comparing LPM/OMEGA modeling of CO_2 reductions for a specific vehicle with the actual CO_2 reduction achieved adopting a wide range of technologies.

Previously, a meaningful comparison could not be conducted because a valid test of the EPA's modeling assumptions requires the simultaneous adoption of multiple technologies that the EPA assumed would be widespread in 2025, and a suitable case-study vehicle did not exist. Now one does after the redesign of the 2018 Toyota Camry. Compared with the baseline 2.5L 2015 Camry, Toyota added for the 2018 model eight new or improved technologies used in EPA modeling. This makes the 2018 Camry an excellent test of the OMEGA model's ability to account for synergies between technologies. This report assesses engine, transmission, and road load improvements to the 2018 Camry and compares CO_2 projections by the OMEGA model using the same technologies with actual CO_2 reductions in the 2018 Camry. If the vehicle meets or exceeds the OMEGA projections—seven years early—that would strongly support the accuracy of the EPA modeling.

Model inputs

The first step was to map the technologies on the 2015 and 2018 Camry to the EPA's technology codes. Table 2 lists the technologies on each vehicle and the associated technology codes. Technology changes coded into the model are highlighted in red, to make it easy to identify the changes from 2015 to 2018. Here is a brief description of each technology:

Oil and engine friction. The 2015 Camry uses 0W-20 oil, and the 2018 Camry uses 0W-16 oil. The EPA codes the base 2015 Camry with EFR1, or engine friction reduction 1, and LUB, for use of 0W-20 engine oil viscosity. While we have not been able to find quantification of the fuel economy benefits of 0W-16, it has lower friction at high temperatures, and there are suggestions that the fuel economy benefit could be significant.[6] Also, EPA modeling of ATK2 engines, or Atkinson cycle engines for non-hybrid vehicles, assumes that they have the EFR2, or

2 The EPA recently announced that as part of its efforts to improve modeling, the functions performed by the LPM will be integrated into the ALPHA model. The EPA is making the maps in ALPHA more realistic and replacing old "development" maps using benchmarking of recent engines. These improvements are not considered here, as the improved model has not been released. However, a recent EPA presentation said: "The revised fleet compliance modeling methodology would be substantially similar to the previous methodology, but with a set of auto-calibrated response surface equations taking the place of the LPM." (EPA Office of Transportation and Air Quality, *Powertrain efficiency in EPA's technical assessment to-date, and plans for ongoing updates* Meeting with AAM and Global Automakers [2017, September 21].) The EPA's future modeling revision thus should not significantly affect the results reported here.

3 The AAM contracted with Novation Analytics for a review of the LPM's calibration from the ALPHA model. That report, *Evaluation of the Environmental Protection Agency's Lumped Parameter Model Informed Projections from the Proposed Determination,* was provided to the EPA as Attachment 3 to the AAM's comments on the Reconsideration of EPA's Final Determination.

4 AAM comments re: Request for Comment on Reconsideration of the Final Determination of the Mid-Term Evaluation of Greenhouse Gas Emissions Standards for Model Year 2022–2025 Light-Duty Vehicles; Request for Comment on Model Year 2021 Greenhouse Gas Emissions Standards (EPA–HQ–OAR–2015–0827; FRL–9966–62–OAR). Submitted to Docket ID No. EPA–HQ–OAR–2015–0827 by AAM on October 5, 2017.

5 EPA Memorandum from Kevin Bolon to Docket EPA-HQ-OAR-2015-0827, Stakeholder Meeting with Novation Analytics and EPA summary presentation on Technical Response to Assertions of 'ALPHA-to-OMEGA Bias'. EPA Office of Transportation and Air Quality, (December 18, 2017). https://www.regulations.gov/document?D=EPA-HQ-OAR-2015-0827-10995

6 Tammy Neal, "The skinny on OW-16 oil," *National Oil & Lube News,* June 30, 2017. https://noln.net/2017/06/30/skinny-ow-16-oil/.

engine friction reduction 2, package.[7] The modeling of the 2018 Camry was run with both EFR1+LUB and EFR2 coding to evaluate the sensitivity of this assumption, but the EFR2 case is considered to be more appropriate.

Cam phasing. The 2015 Camry uses variable valve timing on both intake and exhaust camshaft (dual VVT-i, where "i" means intelligent control). The EPA codes the base 2015 Camry as VVT.[8] The 2018 Camry adds an electric motor on the intake camshaft for faster and more precise control, but the EPA has no coding to reflect this, and the benefits are unknown and likely to be small. So the 2018 model is also coded as VVT.

Transmission. The 2015 Camry uses a 6-speed automatic transmission with electronic controls, which Toyota calls ECT-i. The 2018 Camry also uses ECT-i and increases the number of gears to eight. The 2015 transmission clearly fits the TRX11 transmission code definition, and the 2018 transmission, the TRX21 code.

Steering. Both the 2015 and the 2018 Camry use electric power steering (EPS). Note that there is an error in the EPA's coding for the 2015 Camry, as path 0 for the Camry does not include EPS. To correct for the presence of EPS on the baseline 2015 Camry, we modeled scenarios with and without EPS.

Accessories. The 2018 Camry added variable cooling and a variable oil pump, meaning that both are computer-controlled for increased efficiency. This fits the EPA definition of IACC1 (improved accessories package 1), so IACC1 is added for the 2018 Camry.

Fuel injection. Gasoline Direct Injection (DI) was added for the 2018 Camry engine and is coded as such.

Atkinson cycle and cooled EGR. Both technologies were added for the 2018 Camry and are coded as such. The Camry engine has a 13.0:1 compression ratio and does not have fast engine warmup. Note that ATK2 in the EPA modeling is based on an engine with a 14.0:1 compression ratio and fast engine warmup, with a lower CO_2 penalty on the cold start portion of the Federal Test Procedure (FTP).

Rolling resistance and aerodynamic drag. The 2018 Camry has significantly lower road load coefficients, as shown in Table 1. The road load is about 15% lower at 15 mph and 10% lower at 40 mph. Weighted by the speeds on the FTP and highway cycle, the average road load reduction is about 11% (see Appendix A for details). This is reflected in the modeling by reducing both aerodynamic drag and rolling resistance, using low rolling resistance tires (LRRT), by 10%. This is handled by changing the model inputs from LRRT1 and no aero for 2015 to LRRT2 and Aero1 for 2018.

Table 1. Road load coefficients for 2015 and 2018 Toyota Camry.

	4-cylinder – 3,500 pounds ETW	
Coefficients	**2015**	**2018**
A	27.232	21.006
B	0.04319	0.17604
C	0.019374	0.016028

ETW = Equivalent test weight.
See Appendix A for discussion of road load coefficients.

Performance. While not a technology change, the EPA's modeling assumes that vehicles maintain constant levels of performance when adding technology. Thus, any change in performance also needs to be evaluated for tradeoffs with efficiency. Performance is proportional to the power-to-weight ratio of the vehicle, so both weight and performance changes need to be evaluated. The base 2015 and 2018 Camrys were both tested at 3,500 equivalent test weight (ETW), and

Table 2. Actual Camry technology, 2015 and 2018, and EPA coding. Changes from the 2015 Camry to the 2018 Camry are highlighted in red.

	Actual Camry technology		EPA coding		
	2015	**2018**	**path 0**	**2015**	**2018**
Oil	0W-20	0W-16	LUB	LUB	LUB / —
Engine friction			EFR1	EFR1	EFR1 / EFR2
Cam phasing	dual VVT-i	VVT-iE (I)	VVT	VVT	VVT
Transmission	6A w ECT-i	8A w ECT-i	TRX11	TRX11	TRX21
Steering	electric	electric		EPS	EPS
Accessories		var. cooling & oil pump			IACC1
Fuel injection	SPI	DI + SPI			DI
Atkinson cycle		13:1 CR			ATK2
EGR		cooled			cEGR
Rolling resistance		-11.3 % road load	LRRT1	LRRT1	LRRT2
Aero	Cd = 0.28				Aero1
Weight (ETW)	3,500 pounds	3,500 pounds			

7 Note that LUB is removed from the model inputs when EFR2 is added, as LUB is included in the EFR2 package.

8 Note that the LPM codes dual-VVT as dual cam phasing.

even their curb weight differed by less than 10 pounds. However, the 2018 Camry engine has significantly greater power than the 2015 Camry, with horsepower increasing by 14% from 178 to 203 and torque rising by 8% from 170 ft-lb to 184 ft-lb. In addition, the number of transmission gears increased from six to eight, which also increases performance by keeping the engine at higher rpm after each shift and providing higher gear multiplication for launch. While the actual performance improvement is clearly more than 10%, for the purposes of this comparison the performance gain is conservatively estimated at 10%. This reduces the downward adjustment of the modeled fuel economy to reflect the fuel economy/performance tradeoff and thus causes the modeled fuel economy to be slightly overstated.

Analysis

Table 3 presents actual CO_2 emissions for the 2015 and 2018 Camry from EPA test car lists and compares the findings with the modeled results for the technology packages applied specifically to the Camry.[9]

Comparing the "2018 actual" row, where EFR2 *is* included in the 2018 Camry technology, the reductions achieved by the 2018 Camry do not quite match the reductions projected by EPA modeling. The actual CO_2 emissions are very close, just 1.0 g/mi, or 0.5%, higher than the modeled result. In part this reflects that the 2015 baseline CO_2 in the modeling is 2.7 g/mi higher than the actual readings. The percentage reductions from 2015 to 2018 were 19.9% for the modeling results and 18.6% for the actual 2018 Camry.

Table 3. Actual CO_2 emissions for 2015 and 2018 Camry compared with modeled results for specific technology packages.

	gCO_2/mi		Model	% reduction vs 2015 Camry		
	Actual veh.	**Model**	**reduction v no-tech**	**Actual**	**Model**	
OMEGA tech path 0		237.5	15.2%			
2015 actual	232.0	234.7	16.2%			
2018 actual w/o EFR2	188.9	189.9	32.2%	18.6%	19.1%	
2018 actual	188.9	187.9	32.9%	18.6%	19.9%	
Adjustments					**Adj. Model**	**CO_2 adj.**
14:1 to 13:1 CR	188.9			18.6%	19.0%	+ 1.2%
+10% performance	188.9			18.6%	17.7%	+ 1.5%

However, this is not the most appropriate comparison, as the modeling results assume a 2025 powertrain with additional optimization and improvements beyond those incorporated in the 2018 Camry and assume constant vehicle performance. As noted above, the 2018 Camry uses a 13.0:1 compression ratio, while EPA modeling assumes 14.0:1, the Camry does not have the fast engine warmup assumed in EPA modeling, and the 2018 Camry has at least 10% better performance than the 2015 Camry.

Based on a 2014 paper by Speth et al.,[10] the brake efficiency improvement for increasing compression ratio from 13:1 to 14:1 is 0.9%.[11] Modeling in this paper conducted with Autonomie found that the fuel-consumption reduction, if performance is maintained, is 1.32 times the brake efficiency improvement. So increasing the compression ratio from 13:1 to 14:1 would reduce fuel consumption by 1.19%. Applying this to the 2018 Camry modeling narrows the percent reduction from 19.9% to 19.0% percent—only 0.4% more than the actual reduction of the 2018 Camry compared with the 2015 Camry.

OMEGA assumed constant performance for all of the modeling results. However, the 2018 Camry has significantly better performance than the 2015 Camry, as noted above. For modeling purposes, the overall performance gain was conservatively estimated to be 10%. While there is no consensus on the tradeoff between performance and fuel consumption, it can be derived from the impacts of

9 The file MS_Control_in2025AB_20161118_icm_aeoR_ScenarioPackages was used to generate the model results. A description of the OMEGA model and links to download the model, including this file, can be found at: https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases

10 Raymond L. Speth, Eric W. Chow, Robert Malina, Steven R. H. Barrett, John B. Heywood, and William H. Green, "Economic and Environmental Benefits of Higher-Octane Gasoline," Environmental Science & Technology, 2014, 48 (12), 6561-6568 DOI: 10.1021/es405557p. https://pubs.acs.org/doi/abs/10.1021/es405557p

11 This is extrapolated from the modeled results, as the benefits of increasing compression ratio decrease as the baseline compression ratio increases. For example, the paper found that increasing the compression ratio from 10.5:1 to 11.5:1 would improve brake efficiency by 1.9%, or more than twice the 0.9% benefit of increasing from 13:1 to 14:1. See Appendix B for details.

weight reduction on fuel economy.[12] Reducing weight by 10% results in about a 5.2% decrease in fuel consumption with a 10% increase in acceleration. Reducing weight by 10% while maintaining constant levels of performance, for example by downsizing the engine, results in about a 6.6% decrease in fuel consumption. Thus, the impact of increasing performance by 10% results in roughly a 1.5% increase in fuel consumption or CO_2 emissions.

Applying this performance adjustment to the 2018 Camry modeling drops the modeled reduction from 19.0% to 17.7%—significantly less than the actual 18.6% reduction of the 2018 Camry versus the 2015 Camry.

Note that this result does not account for calibration improvements from 2018 to 2025. Minor improvements to technologies and calibrations are routine and will certainly increase the CO_2 reduction that can be achieved with this technology set by 2025. Also note that a likely conservative adjustment was made for the impact of the improved performance of the 2018 Camry on fuel economy, plus no adjustment was made for the lower cold start fuel consumption included by OMEGA in their ATK2 technology, which is also conservative.

12 Details of the calculation of the tradeoffs between fuel economy and performance are in Appendix B. Note that Appendix B also provides an example of the 2018 Honda Accord, which uses a similar turbocharger system on both the base 1.5L and the optional 2.0L engines. Compared with the 1.5L Accord engine, the 2.0L engine increases horsepower by 31% from 192 to 252, and torque, by 42% from 192 ft-lb to 273. Using the 6-speed manual as the control (as the automatics are different for the 1.5L and the 2.0L), the 1.5L is rated at 30 mpg and the 2.0L at 26 mpg, or 13% lower. So, for every 10% increase in performance on this engine, fuel economy decreased by about 4%—or over 2.5 times the amount calculated from the weight-reduction formulas.

Comparison with footprint targets

The 2018 2.5L Camry meets its 2022 footprint target without any consideration of air conditioning or off-cycle credits, without weight reduction, and without any kind of hybridization, not even stop/start.[13] Just maximizing off-cycle credits of 10 grams of CO_2 per mile (g CO_2/mi) and air conditioning efficiency credits of 5 g CO_2/mi would allow the Camry to almost meet the 2024 targets. The Camry still has seven years to make modest improvements and can easily reach its 2025 target by adding a stop/start system, with modest reductions of weight, aerodynamic drag, or tire rolling resistance, or even petitioning the EPA for additional off-cycle credits beyond those listed in the off-cycle menu.

Conclusion

Before considering differences in performance, OMEGA modeling of the technology improvements in the 2018 Camry almost exactly matches the actual reductions achieved by the vehicle after adjusting for technology differences, such as lower compression ratio and higher CO_2 after cold start. However, this does not take into account the much higher performance of the 2018 Camry. After properly adjusting for the performance gains, the 2018 Camry achieved a CO_2 reduction of 18.6%, significantly greater than the 17.7% predicted by the adjusted OMEGA modeling. And this is without accounting for seven more years of development and calibration improvements and the reductions in cold start fuel consumption modeled by OMEGA, plus a likely conservative performance adjustment. This confirms that the OMEGA model properly accounts for synergies between technologies and does not overpredict technology benefits. In fact, its projections are most likely conservative.

13 John German, "Technology Leapfrog: Or, all recent auto technology forecasts underestimate how fast innovation is happening," ICCT blog, September 25, 2017. https://www.theicct.org/blog/staff/technology-leapfrogging

Another unavoidable conclusion is that the Novation critique of EPA modeling is demonstrably wrong. There is clearly no systematic bias in the LPM, and the 2018 Camry can easily meet its 2025 targets without hybridization beyond possibly a stop/start system. This further suggests that Novation's analyses are not properly constructed and that the bias exists in Novation's modeling, not the EPA's.

APPENDIX A
Rolling resistance and aerodynamic drag

Road load coefficients are generated using a coast-down test on a track. For a given vehicle weight, the longer it takes for the vehicle to lose velocity, the lower the tire rolling resistance or aerodynamic drag, or both. The vehicle speed versus time curve is fitted using A, B, and C coefficients, where the A coefficient is a fixed value regardless of speed, B is a function of vehicle speed, and C is a function of the square of vehicle speed.

The 2018 Camry had significantly lower A and C road load coefficients than the 2015 Camry, although the B coefficient was higher (see Table A-1).

Table A-1. Road load coefficients for 2015 and 2018 Toyota Camry.

	4-cylinder – 3,500 pounds ETW	
Coefficients	**2015**	**2018**
A	27.232	21.006
B	0.04319	0.17604
C	0.019374	0.016028

ETW = Equivalent test weight.

Figure A-1 illustrates the total road load from the A, B, and C coefficients at different vehicle speeds.

Figure A-2 shows the speed distribution on the FTP and highway test cycles. Weighting the 2015 and 2018 2.5L Camry road load (blue and red lines in Figure A-1) by the FTP speed distribution (blue line in Figure A-2) yields an average road load reduction of 12.8%, and weighting by the highway speed distribution (red line in Figure A-2), 10.4%. Finally, weighting the FTP and highway results by 55% city and 45% highway yields an overall average road load reduction of 11.3%.

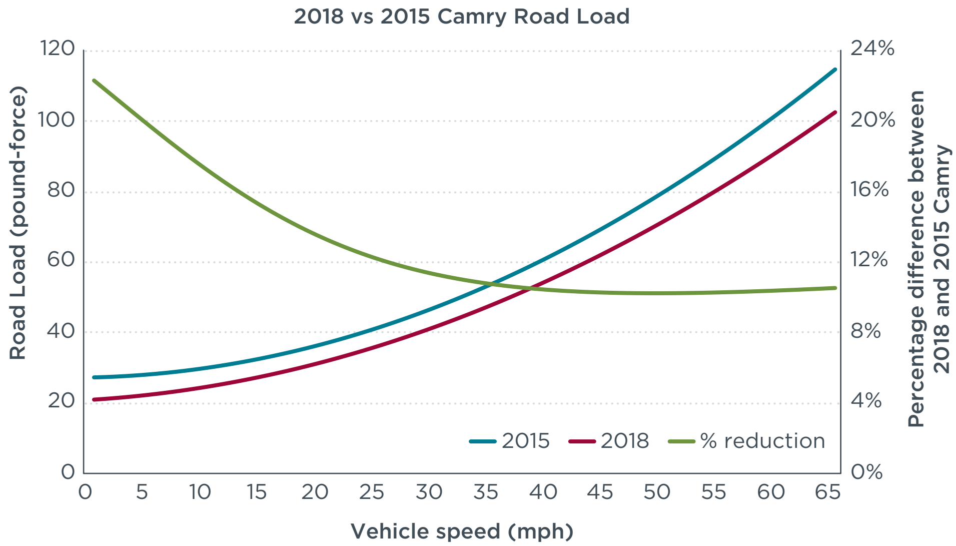

Figure A-1. Road load comparison of 2018 and 2015 2.5L Camry.

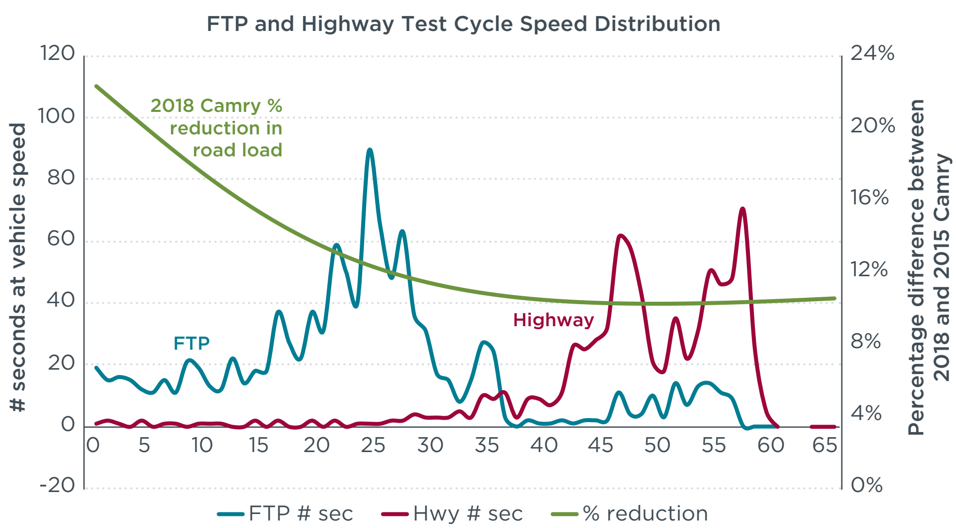

Figure A-2. FTP and highway test cycle speed distributions and related reductions in road load for 2018 Camry compared with 2015 Camry.

APPENDIX B
Performance tradeoffs with fuel economy

The tradeoff between performance and fuel consumption is difficult to calculate. Theoretically the fuel-consumption increase with improving performance should diminish in the future as engines improve fuel consumption at low engine loads. No consensus has been reached on how to quantify the tradeoff.

The approach taken here is to derive the performance versus fuel economy tradeoff from the impacts of weight reduction on fuel economy. Reducing weight affects both fuel consumption and performance. Most studies of the impacts of weight reduction have found that a 10% weight reduction directly results in about a 4.5% decrease in fuel consumption. To generalize the CO_2 effects of mass reduction, as part of an ICCT study on European post-2020 CO_2 standards, ICCT performed a detailed analysis of 26 technology packages developed by FEV (spanning all modeled vehicle classes) where mass reduction was the only technology variant.[14] The results of this evaluation revealed average CO_2 emission changes of 0.456%, 0.467 %, and 0.447% per % change in vehicle mass for vehicles executing the NEDC, WLTP low road-load, and WLTP high road-load cycles, respectively. While not listed in this report, the same methodology applied to the US cycles revealed average CO_2 emission changes of 0.596% and 0.426% per % change in vehicle mass for vehicles executing the FTP and highway test cycle, respectively. Weighting the FTP and highway results by 55%/45% yields

14 Dan Meszler, John German, Peter Mock, and Anup Bandivadekar, *CO_2 reduction technologies for the European car and van fleet: a 2025-2030 assessment methodology and summary of compliance costs for potential EU CO_2 standards*, (ICCT: Washington, DC, November, 2016). https://www.theicct.org/sites/default/files/publications/EU-Cost-Curves_ICCT_nov2016.pdf

an average of 0.520% per % change in vehicle mass.

However, 10% weight reduction also improves performance by 10%. Modeling of the impact of weight reduction while maintaining constant levels of performance—for example, by downsizing the engine—is difficult, as it is affected by powertrain characteristics, vehicle attributes, and how the performance is adjusted. A more reliable method is to evaluate the change in the total energy required to drive a vehicle over a specific drive cycle. ICCT developed such a method as part of the 2016 ICCT study on European post-2020 CO_2 standards. It was later applied to the US FTP and highway test cycles to generate lightweighing benefit inputs to the OMEGA model.[15] Because the relationship between the various road-load parameters (i.e., mass, rolling resistance, and aerodynamic drag) varies across vehicles, estimates were made for six different types of vehicles. The mid-size car estimate was a 6.6% decrease in fuel consumption for a 10% weight reduction. Thus, the impact on fuel economy of increasing performance by 10% is roughly the fuel-economy impact without correcting for performance, or 1 – 5.2% = 94.8%, divided by the fuel-economy impact after correcting for performance, or 1 - 6.6% = 93.4%. This yields about a 1.5% increase in fuel consumption or CO_2 emissions with a 10% improvement in performance.

The 2018 Honda Accord provides a quick check on the accuracy of this calculation. The vehicle offers a good comparison, using a similar 4-cylinder turbocharger system on both the base 1.5L and the optional 2.0L engines, and each engine can be paired with a manual 6-speed transmission. This minimizes the confounding factors of different engine types, number of cylinders, and transmissions.

As shown in Table B-1, the 2.0L engine is rated at 252 horsepower, 31% more than the 1.5L's 192. The 273 ft-lb of torque for the 2.0L is 42% higher than 192 ft-lb for the 1.5L. Using the 6-speed manual as the control, because the automatics are different for the 1.5L and the 2.0L, the 1.5L is rated at 30 mpg and the 2.0L at 26 mpg, or 13% lower. So, for every 10% increase in horsepower, fuel economy decreased by 4.3%, and for every 10% increase in torque, fuel economy dropped by 3.2%. Overall, for a 10% gain in performance, fuel economy fell by roughly 4%. This is over 2.5 times the amount calculated from the weight-reduction formulas, indicating that the performance adjustment used for the 2018 Camry is most likely conservative.

Table B-1. 2018 Honda Accord performance and fuel economy comparison.

2018 Honda Accord w/ M6 transmission			
	HP	**ft-lb**	**MPG**
1.5L	192	192	30
2.0L	252	273	26
% change	31.3%	42.2%	-13.3%
MPG decrease per 10% HP/ft-lb increase	-4.3%	-3.2%	

15 Nic Lutsey, Dan Meszler, Aaron Isenstadt, John German, and Josh Miller, *Efficiency technology and cost assessment for 2025-2030 light-duty vehicles,* (ICCT: Washington, DC, 22 March, 2017). https://www.theicct.org/publications/US-2030-technology-cost-assessment