THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

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September 26, 2016

RE: Notice of Availability of Midterm Evaluation Draft Technical Assessment Report for Model Year 2022–2025 Light Duty Vehicle GHG Emissions and CAFE Standards

The International Council on Clean Transportation (ICCT) welcomes the opportunity to provide comments on the *Draft Technical Assessment Report* of the U.S. Environmental Protection Agency, California Air Resources Board, and the National Highway Traffic Safety Administration. The ICCT is an independent nonprofit organization founded to provide unbiased research and technical analysis to governments in major vehicle markets around the world. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation, as well as their fuels, in order to benefit public health and mitigate climate change.

We welcome this chance to comment on the U.S. and California governments' efforts to mitigate global climate change and reduce the demand for oil in the transport sector. We commend the agencies for their continuing efforts to promote a more efficient and lower carbon economy. We hope these comments can help the agencies to fully meet their requirements to establish maximum feasible and appropriate standards.

We would be glad to clarify or elaborate on any points made in the attached comments. If there are any questions, EPA, CARB and NHTSA staff can feel free to contact our U.S. program co-Leads, John German (*john@theicct.org*) and Nic Lutsey (*nic@theicct.org*).

Best regards,

Drew Kodjak
Executive Director
International Council on Clean Transportation

International Council on Clean Transportation comments on the *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025*

Public submission to

U.S. Environmental Protection Agency
EPA Docket ID: EPA-HQ-OAR-2015-0827

National Highway Traffic Safety Administration
NHTSA Docket ID: NHTSA-2016-0068

September 26, 2016

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

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I. Summary

The International Council on Clean Transportation (ICCT) provides these comments to the *Draft Technical Assessment Report* (referred to as "TAR" in the following text) of the U.S. Environmental Protection Agency, California Air Resources Board, and the National Highway Traffic Safety Administration. The intent of these comments is to support the agencies in their technical determination of the appropriateness of 2022-2025 standards for light-duty vehicles.

The agencies have added an immense amount of new data on technology developments that have occurred since the rulemaking. This level of technical scrutiny of a vehicle regulation is, as far as the ICCT is aware, unprecedented globally by a very large margin. The transparency and availability of the data upon which to make a regulatory determination is also without parallel. The new data is thoroughly and transparently presented in the TAR and its Appendix. In addition, most of the dozens of supporting technical reports, most of which took the extra steps of expert peer-reviews, have been made available by the agencies well in advance of the TAR release. This has been very helpful for stakeholders that are interested enough to delve deeper into the technical details. The comprehensive technical work, public process, and transparency are to be commended.

In terms of the technical substance, we are generally supportive of the TAR analysis. This massive new body of work makes is clear that the efficiency and CO_2 standards for 2022-2025 model years are built on a strong technical foundation and can be met with cost-effective technologies. However, in the comments below, we do note several areas where the agencies could consider additional technology and cost inputs. These areas generally indicate that (a) there is greater technology availability that will reduce costs from what the agencies indicate and (b) there is also much more available and emerging technology to develop more stringent standards beyond 2025.

II. Detailed comments on input data on technologies

We are generally very supportive of the technical analysis conducted by the agencies. We concur with the major findings that the standards are working as designed, that there are many technical paths to comply with the 2025 standards with combustion technology, that automaker innovation is outpacing what the agencies projected in 2012, and that the costs are complying appear to be similar or lower than originally projected.

There is much to commend in the updated agency analyses, as documented in the TAR. The agencies have done massive amounts of work to update the technologies and the technology assessments since the 2017–2025 rulemaking. The most significant change was the addition of new highly-efficient, cost-effective naturally aspirated engines (i.e., high-compression Atkinson engines, like Mazda's SkyActiv) in EPA's analyses. This resulted in a reduction in the penetrations of turbo downsizing and hybridization for the EPA modeling. Both agencies also implemented a number of other updates, including a more cost effective 48-volt mild hybrid system, Miller-cycle turbocharging, variable geometry turbocharging, updated mass reduction costs, increased effectiveness of future 8-speed transmissions, updated battery cost modeling, and improved on-cycle stop-start effectiveness modeling. These improvements all reflect automaker and supplier innovations that are occurring and entering production. EPA's new physics-based Alpha model and offers a nice enhancement in modeling multiple technologies.

The agencies are also to be commended for their expanded use of rigorous peer-reviewed "tear-down" cost studies. Although expensive to conduct, these studies are typically more accurate and far more transparent than the older method of surveying manufacturers. Note that the 2015 National Academy of Science report specifically endorsed tear-down studies as the most appropriate way to get at costs. We also note that EPA and NHTSA both employ detailed and rigorous analytical methods and show relatively similar results, even though they conducted relatively independent analyses. This supports the robustness of the technology availability assessment and how there are multiple cost-effectiveness paths to comply with the 2025 standards.

Still, despite all of their new work and all of the updates, there are some key areas where the agencies' analysis is still somewhat behind what is already happening in the market. For example, the agencies did not explicitly model e-boost, variable compression ratio, or dynamic cylinder deactivation. This is understandable, as it is critical for the agencies to have a robust, defensible analysis. But it also means that the agencies are always going to be somewhat behind in their assessments of potentially promising technologies. This may be particularly a concern for the NHTSA results, as it appears that NHTSA used slightly older data for some of their analyses and did not model the new high compression ratio naturally aspirated engines across the fleet.

We emphasize that the single most important factor in the accuracy of cost and benefit for projections is the use of the latest, most up to date technology data and developments. Using older data guarantees that the cost of meeting the standard will be overstated, as it does not include more recent technology developments and thus must default to more expensive technology, such as full hybrids. Assuming that the end of innovation has been reached and basing projections on what is in production today ignores technology developments in process and overstates the cost of future compliance. In areas mentioned below, we suggest the agencies examine the latest technology developments and ensure that their technologies assessments include all existing and automaker-announced technologies as generally applicable by 2025. We also encourage the agencies to project how individual technologies will greatly improve over that period in cost and effectiveness, based on leading technology developers at auto manufacturing and supplier companies.

In preparation for the mid-term term review, ICCT has collaborated with automotive suppliers on a series of working papers evaluating technology progress and new developments in engines, transmissions, vehicle body design and lightweighting, and other measures that have occurred since then. The papers combine the ICCT's extensive analytical capacity and expertise in vehicle technology with the practical knowledge and experience of auto suppliers. Each paper evaluates how the current rate of progress (cost, benefits, market penetration) compares to projections in the rule, recent technology developments that were not considered in the rule and how they impact cost and benefits, and customer-acceptance issues, such as real-world fuel economy, performance, drivability, reliability, and safety.

Eaton, Ricardo, Johnson Controls, Honeywell, ITB, BorgWarner, Dana, FEV, Aluminum Association, Detroit Materials, and SABIC have contributed to one or more of the technology papers. Papers on the following technologies are part of this series (three of the papers have been published, and the remainder will be published by the end of 2016:

- Hybrid vehicles[1]
- Downsized, boosted gasoline engines[2]
- Naturally aspirated gasoline engines, including cylinder deactivation[3]
- Transmissions[4]
- Lightweighting[5]
- Thermal management[6]
- Diesel engines[7]

The following technology discussion summarizes some of the most significant findings from these papers. The papers discuss many other technology developments, cost reductions, and consumer acceptance issues that can also help inform the mid-term evaluation and should be considered by the agencies. In addition, ICCT's European office contracted with FEV of Europe to develop updated cost and efficiency estimates to help assess technology availability in the European context in the 2025 timeframe.[8] The results from FEV's analyses can help inform the mid-term evaluation.

Engine technology

The inclusion of new engine technologies generally reflects emerging technologies being deployed by suppliers and automakers since the original rulemaking. We first summarize noteworthy technology findings from the supplier literature. Then we note several engine technology developments where it appears that the agencies might be too conservative or restrictive in their technology assessment. For more information see the joint ICCT/supplier technology papers on naturally aspirated engines, downsized turbocharged gasoline engines, and thermal management.

High-efficiency naturally aspirated engines with Atkinson cycle and high compression ratio. The rulemaking assessments found that naturally aspirated engines would not be able to compete with turbocharged, downsized engines and would be almost completely replaced with turbocharged engines by 2025. The only exception was the continued use of Atkinson cycle engines on full hybrids (5% of the fleet), where the electric motor could offset the performance tradeoffs with the Atkinson cycle engine. However, Mazda has introduced a very high (13.0:1) compression ratio naturally aspirated engine with exceptional efficiency and is

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1 *John German (ICCT). Hybrid vehicles: Trends in technology development and cost reduction, July 23, 2015. http://www.theicct.org/hybrid-vehicles-trends-technology-development-and-cost-reduction*

2 *Aaron Isenstadt and John German (ICCT); Mihai Dorobantu (Eaton); David Boggs (Ricardo); Tom Watson (JCI). Downsized boosted gasoline engines. In final review*

3 *Aaron Isenstadt and John German (ICCT), Mihai Dorobantu (Eaton). Naturally aspirated gasoline engines and cylinder deactivation, June 21, 2016. http://www.theicct.org/naturally-aspirated-gas-engines-201606*

4 *Aaron Isenstadt and John German (ICCT), Mark Burd and Ed Greif (Dana Corporation). Transmissions, August 29, 2016. http://www.theicct.org/PV-technology-transmissions-201608*

5 *Aaron Isenstadt and John German (ICCT); Piyush Bubna and Marc Wiseman (Ricardo Strategic Consulting);); Umamaheswaran Venkatakrishnan and Lenar Abbasov (SABIC); Pedro Guillen and Nick Moroz (Detroit Materials); Doug Richman (Aluminum Association), Greg Kolwich (FEV). Lightweighting. In final review.*

6 *Sean Osborne, Dr. Joel Kopinsky, and Sarah Norton (The ITB Group); Andy Sutherland, David Lancaster, and Erika Nielsen (BorgWarner); Aaron Isenstadt and John German (ICCT). Automotive Thermal Management Technology. In final review.*

7 *Diesel technology paper is in development and should be published by December 2016.*

8 *FEV. 2025 Passenger Car and Light Commercial Vehicle Powertrain Technology Analysis. September 2015.*

already using this on most of their vehicles.[9] Toyota has found ways to offset the performance losses with its Atkinson cycle engine, using variable valve timing and other techniques, and is expanding the use of Atkinson cycle engines to non-hybrid vehicles.[10] Toyota has announced that this technology will be in production soon.

Dynamic cylinder deactivation. Cylinder deactivation was considered by the Agencies in the rulemaking, but only deactivation of groups of cylinders at a time. A new type of cylinder deactivation is in widespread development that allows each individual cylinder to be shut off every other revolution of the engine.[11] This technique reduces noise and vibration, extending cylinder deactivation to lower engine rpms and allowing 4-cylinder and even 3-cylinder engines to use cylinder deactivation. The agencies did not appear to explicitly model dynamic cylinder deactivation, and this technology could be quite important in the 2025 fleet.

Miller cycle for turbocharged engines. This is basically the higher-efficiency Atkinson cycle concept extended to turbocharged engines. The performance tradeoff can be addressed by increasing the turbocharger boost. Miller cycle adds about 5% efficiency to a turbocharged engine at no cost, although there can be costs involved with increasing the turbocharger boost to compensate for the performance loss. If Miller cycle is combined with e-boost or 48v hybrids, these technologies provide the needed performance boost and the cost of Miller cycle becomes zero. The first Miller cycle application is in production on the new EA211 engine from VW.[12]

Variable Compression Ratio (VCR). Higher compression ratio improves efficiency, but at high engine loads it increases detonation, which is especially a problem for boosted engines. Variable compression ratio (VCR) changes the engine's compression ratio to suit particular speeds and loads. The benefits of VCR overlap with those of Atkinson/Miller cycle, as both enable higher compression ratio. However, VCR does have one significant benefit over Miller cycle: it allows performance to be completely maintained at lower engine speeds. Thus, VCR may be a competitor to Miller cycle concepts in the long run, offering manufacturers more options to improve efficiency while maintaining performance. Nissan is implementing the first

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9 *Goto et al. "The New Mazda Gasoline Engine Skyactiv-G." MTZ worldwide Issue no.: 2011-06: 40-46. Accessed June 2016. http://www.atzonline.com/Artikel/3/13208/The-New-Mazda-Gasoline-Engine- Skyactiv-G.html*

10 *"Toyota claims record gasoline efficiency." Ricardo Quartlery Review Q2 2014, p. 4. Accessed June 2016. http://www.ricardo.com/Documents/RQ%20pdf/RQ%202014/RQ%20 Q2%202014/RQ_Q2_2014_English.pdf*

11 *Wilcutts, M., Switkes, J., Shost, M. and Tripathi, A., "Design and Benefits of Dynamic Skip Fire Strategies for Cylinder Deactivated Engines," SAE Int. J. Engines 6(1):2013, doi:10.4271/2013-01-0359. Truett,Richard. "Cylinders take turns to deliver proper power." Auto News September 21, 2015. Accessed June 2016. http://www.autonews.com/article/20150921/OEM06/309219978/cylinders-take-turns-to- deliver-proper-power. "VW ACT Active Cylinder Management." Automotive Expo. YouTube, April 2014. Accessed June 2016. https://www.youtube.com/watch?v=_4AZbbBjqhM. Cecur, Majo, Veiga-Pagliari, D.R. "Dynamic Cylinder De-Activation (D-CDA)." PSA & Eaton. Presented at 24th Aachen Colloquim Automobile and Engine Technology. October 7, 2015.*

12 *Eichler, F. et al (2016). The New EA211 TSI® evo from Volkswagen. Presented at the 37th International Vienna Motor Symposium, 28-29 April 2016. "Audi introduces new high-efficiency 2.0L TFSI based on Miller cycle; 190 hp, 47 mpg," Green Car Congress, accessed 18 August 2016, http://www.greencarcongress.com/2015/05/20150708-audi.html*

12 *Ichiro Hirose (2016). Mazda 2.5L SKYACTIV-G Engine with New Boosting Technology. Presented at the 37th International Vienna Motor Symposium, 28-29 April 2016.*

VCR application in a production turbocharged engine in MY2017.[13] The agencies did not appear to explicitly model variable compression ratio technologies that could be quite important in the 2025 fleet.

Technology paths and combinations. There appears to be technology evolution that goes beyond the constraints being used by the agencies in their modeling. Nissan's variable compression ratio is achieving compression rations up to up to 14:1. Volkswagen and Audi are "Millerizing" their turbocharging technology for 1.4L and 2.0L engines for higher compression ratio (initially up to a 11.7:1 level). The technology options by EPA seems to show an *either/or* technology path between Atkinson/high-compression *or* turbocharging, whereas various stages of these two technologies are simultaneously available. NHTSA appears to have limited the engine technology options like high-compression engines by automaker, and such constraints impede technology penetration. The agencies also appear to have treated Miller cycle and 2-stage turbocharging as *either/or* technology paths, with 2-stage turbocharging preferred in most cases because of the cost benefits from reduced engine size. This misses the efficiency benefits of adding Miller cycle to 2-stage turbocharged engines – and the efficiency benefits are basically free because the 2-stage turbocharger can compensate for the reduced engine air filling from the Miller cycle.

The examples above show that the agency analysts are being too restrictive on how these new technologies are available and will be widely available by 2025. We recommend that the agencies do not put restrictive constraints on automaker technology paths based on past and near-term automaker technology decisions. In the 2022-2025 timeframe, innovative automaker and supplier technologies are emerging that can be deployed more widely than the agencies indicate. This was of course a key advantage of setting regulatory standards with such a long lead time – that there is time for widespread diffusion of emerging technologies across companies.

Lightweighting technology

The agencies continue to systematically underestimate the extent to which lightweighting technology is available and could penetrate the fleet. The agencies' projection for model year 2025 actually went down from about 7% lightweighting technology to about 6% in the TAR. Automaker are deploying greater amounts of mass-reduction technology and the agencies appear to continue to use contrived mass-reduction constraints that do not reflect automakers own confidence in safely reducing mass of vehicles.

Advances in modeling/simulation tools and joining techniques have opened the floodgates to unprecedented levels of material/design optimization. Suppliers are rapidly developing the advanced materials and methods for major lightweighting endeavors, as well as the computational tools for simulating full vehicles all the way down to nanoscopic material behavior. Many recent vehicle redesigns have reduced weight by at least 4%, already meeting or exceeding 2021 projections in the rule (Table 1). There are numerous material improvements in development that were not considered in the rule, such as higher strength

[13] *Nissan Global. (2016). Infiniti VC-T: The world's first production-ready variable compression ratio engine. August 14, 2016, https://newsroom.nissan-global.com/releases/infiniti-vc-t-the-worlds-first-production-ready-variable-compression-ratio-engine*

aluminum,[14] improved joining techniques for mixed materials, third-generation steels with higher strength and enhanced ductility,[15] a new generation of ultra-high strength steel cast components, and metal/plastic hybrid components.[16] These developments are just a sample of the developments discussed in the joint ICCT/supplier technology working paper on lightweighting.

The agencies underestimate the likely deployment of lightweighting, especially since reducing vehicle weight has substantial consumer benefits in addition to the fuel savings, such as better ride, handling, braking, performance and payload and tow capacity. These consumer benefits need to be incorporated into the agencies' analyses. The recent redesigns that reduced weight by at least 4% can be duplicated for each of the next two redesign cycles by 2025, likely doubling the agencies' estimate of weight reduction in 2025 to about 15%.

The agencies also appear to overestimate the costs (see many previous works[17] and the ICCT/supplier lightweighting paper). As shown in figure 1 from the ICCT/supplier lightweighting paper, weight reduction from use of aluminum should roughly match the cost estimates in the 2017-25 rulemaking, weight reduction from improved plastics and improved grades of steel should be roughly zero (the increased material cost is roughly offset by the reduced amount of material needed due to the higher strength), and materials/design optimization can reduce both weight and cost (due to the reduced materials needed). These three techniques will all be extensively implemented in the future, with a weighted cost of only about a third of the rulemaking cost projection.

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[14] *Richard Truett. "Novelis: Automakers test stronger aluminum." Auto News. August 10, 2015. Web. Accessed July 2016. http://www.autonews.com/article/20150810/OEM01/308109982/novelis:-automakers-test-stronger-aluminum*

[15] *Ryan Gehm. "NanoSteel confident its new AHSS is ready for volume production." Automotive Engineering. July 17, 2016. Web. Accessed July 2016. http://articles.sae.org/14908/*

[16] *Mana D. et.al "Body-in-white Reinforcements for Light-weight Automobiles", SAE technical paper # 2016-01-0399. Nagwanshi D. et.al, "Vehicle Lightweighting and Improved Crashworthiness – Plastic/Metal Hybrid Solutions for BIW", SPE ANTEC, technical program, 2016.*

[17] *Lotus Engineering (2012) Evaluating the Structure and Crashworthiness of a 2020 Model-Year, Mass-Reduced Crossover Vehicle Using FEA Modeling. Prepared for California Air Resources Board. http://www.arb.ca.gov/msprog/levprog/leviii/final_arb_phase2_report-compressed.pdf*
EDAG (2011) Future Steel Vehicle. http://www.worldautosteel.org/projects/future-steel-vehicle/phase-2-results/. Prepared for WorldAutoSteel
EDAG (2013) Venza Aluminum BIW Concept Study. http://www.drivealuminum.org/research-resources/PDF/Research/2013/venza-biw-full-study. April.
FEV (2012) Light-Duty Vehicle Mass Reduction and Cost Analysis — Midsize Crossover Utility Vehicle. Prepared for US Environmental Protection Agency. EPA-420-R-12-026. http://www.epa.gov/otaq/climate/documents/420r12026.pdf
Singh, H. (2012). Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025. Prepared for National Highway Traffic Safety Administration. Report No. DOT HS 811 666. ftp://ftp.nhtsa.dot.gov/CAFE/2017-25_Final/811666.pdf

Table 1: Sample of vehicle mass reductions

Vehicle Make	Model Year	Weight reduction (kg)	Weight reduction (%)	Relative to
Ford F-150	2016	288	14%	2014
Acura MDX	2017	172	8%	2013
GM Cadillac CTS	2017	95	5%	2013
Audi Q7	2016	115	5%	2015
Chyrsler Pacifica	2017	146	7%	2016
Nissan Leaf	2016	59	4%	2012
Opel Astra	2016	173	12%	2015
Chevrolet Malibu	2016	135	9%	2015
GMC Acadia	2017	318	15%	2016
Chevrolet Volt	2017	110	6%	2014
Chevrolet Cruze	2017	103	7%	2015
Mazda Miata	2016	67	6%	2015
BMW M3/M4	2017	63	4%	2013
Chevrolet Equinox	2018	182	10%	2016
Chevrolet Camaro	2016	177	10%	2015

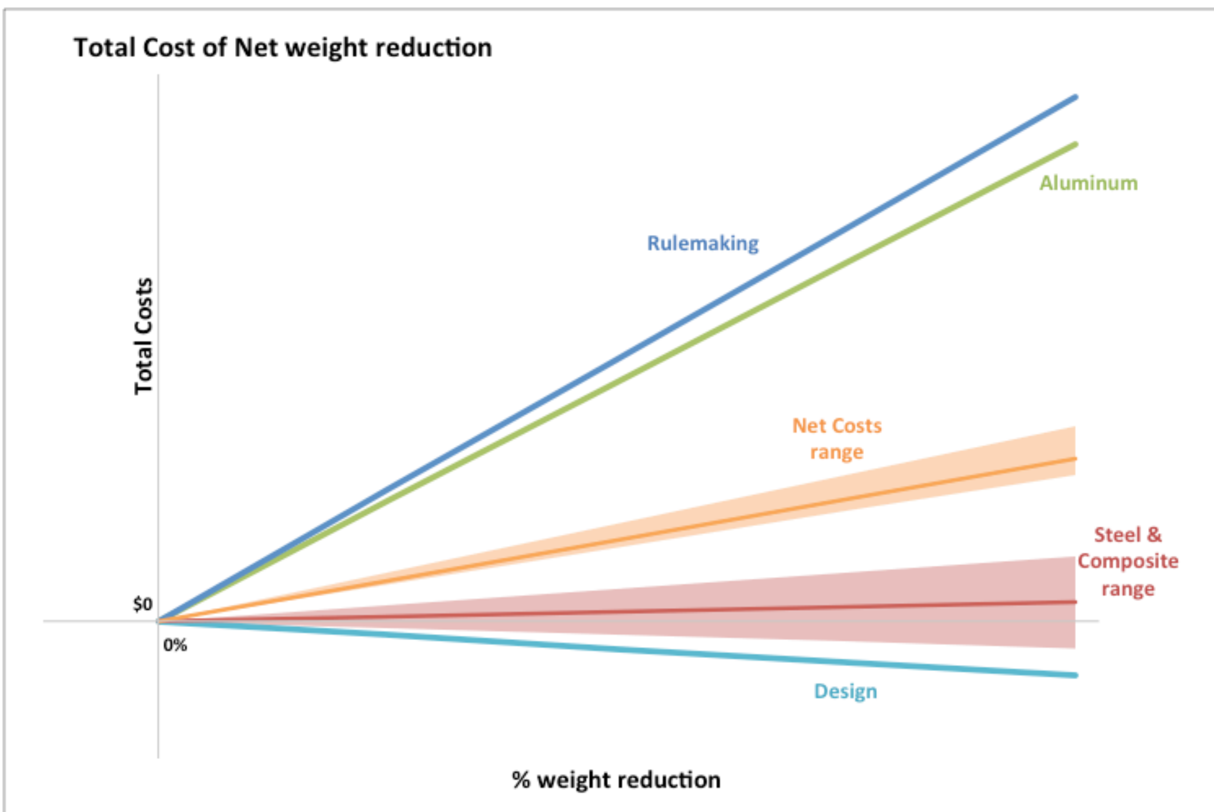

Figure 1. Total cost as a function of % vehicle weight reduction. Note that composites include plastics, but not carbon fiber.

Transmission, e-boost, and hybrid technology

Continuously-variable transmissions (CVTs). The rulemaking analyses found that CVTs would not be able to compete with other transmissions and would be completely replaced by 2025. However, certain long-standing design issues with CVTs have been resolved and the latest generation of CVTs have reduced internal friction, wider ratio spread, and increased torque capacity.[18, 19] These new CVT designs have efficiency similar to conventional automatics and are cheaper than either conventional automatics or dual-clutch automated manuals. As a result, the CVT market share has exploded, from 9% in 2012 to 18% in 2015.

E-boost. These systems comprise a higher voltage electrical system (48 volt) used to provide power for a small electric compressor motor within a turbocharger. This either directly boosts the engine, or spins up the turbocharger to greatly reduce turbo lag. This increases the ability to downsize and downspeed the engine and also reduces backpressure.[20] E-boost further allows the use of larger turbines with lower backpressure, for a direct reduction in BSFC in addition to the benefits from engine downspeeding/downsizing. The total efficiency benefits are likely to be about 5%. The first E-boost system application is in production on the 2017 Audi QS7.[21] The agencies did not appear to explicitly model e-boost technologies, and this technology could be quite important in the 2025 fleet. Note that e-boost has significant cost synergies with both Miller cycle, as the e-boost system can compensate for the performance loss from the Miller cycle, and 48v hybrid systems.

48-volt hybrid systems. Unlike expensive full hybrids, 48v hybrid systems are not designed to power the vehicle. The lack of a large electric motor and the correspondingly smaller battery greatly reduce the cost for this level of hybridization. The rulemaking considered 110-volt mild hybrid systems and projected that they would capture 17% of the market by 2025. However, 48v systems provide much of the same benefits at lower cost, as they stay below the 60v lethal threshold, also improving safety.[22] There are also excellent cost synergies with e-boost, as the same 48v controllers, inverters, and power electronics are used for both systems. We note that the TAR adds analyses of 48v hybrid systems, but we recommend that the agencies investigate the synergies between 48v hybrids and e-boost systems.

Full hybrids. Much has been made of the market drop in full hybrid vehicles, corresponding to the drop in fuel prices. While full hybrids are sensitive to fuel prices, this is a very expensive technology that is not typical of the technologies available to comply with the standards. Most technologies are much lower cost and will not engender the same consumer resistance. This includes 48v hybrids that are only about 40% of the cost of a full hybrid and are projected by both ICCT and the agencies to capture a much larger share of the market in 2025 than full

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18 *"Jatco CVT7." Jatco Product Information. http://www.jatco.co.jp/ENGLISH/products/ cvt/cvt7.html. Accessed June 2016.*

19 *Isenstadt, A., German, J., Burd, M., Greif, E. Transmissions. International Council on Clean Transportation. http://www.theicct.org/PV-technology-transmissions-201608*

20 *BorgWarner (2015). Technologies for enhanced fuel efficiency with engine boosting. Presented at Automotive Megatrends USA 2015, 17 March 2015. Slide 26*

21 *Stuart Birch. "Audi claims first production-boosting on 2017 SQ7," Automotive Engineering, March 6, 2016, http://articles.sae.org/14662/*

22 *Alex Serrarens (2015). Overview of 48V technologies, deployment and potentials. Presented at Automotive Megatrends USA 2015, 17 March 2015.*

hybrids.[23]. Full hybrids (nor going further with plug-in electric vehicles) are not needed to comply with the 2025 standards for most companies. Between the technologies that are already near production that were not included in the agencies' assessments in the TAR and the low penetration of Miller cycle and weight reduction projected for 2025, conventional technology will be more than enough for manufacturers to comply with the standards.

Electric vehicle technology

As stated above, we believe that electric vehicles are by and large unnecessary to minimally comply with the 2025 CO_2 standards. However, the agencies have accurately reflected how the prospects for electric vehicles have improved markedly in just the past several years, and that many companies are deciding to innovate and deploy technology in this area. EPA's incorporation of industry compliance with the California Air Resources Board's Zero-Emission Vehicle regulation as part of its reference fleet assessment is appropriate. This is appropriate as it reflects a clear industry trend to, at a minimum, comply with ZEV standards, and follows the agencies' precedent of included adopted regulatory compliance in the baseline fleet projection.

It is likely that the agencies' projection of electric vehicle deployment is less than what many companies will achieve in the 2025 timeframe. In 2014 and 2015, California electric vehicle deployment represented over 3% of new vehicle sales in the state. In CARB's 2012 regulatory assessment they projected that ZEV compliance would only deliver a 1.5% share of new vehicles in the 2014, and remain below 3% share of new vehicles through 2017. Based on these trends, we are seeing that industry as a whole is at least 3-4 years in front of the ZEV requirements. Many companies, like General Motors, Nissan, Ford, and BMW are further out in front, greatly over-complying with the ZEV standards. Considering the market success of these advanced electric-vehicle technologies and over-compliance with adopted ZEV regulation, the NHTSA regulatory modeling framework appears to be out of step with industry, regulatory, and market dynamics by not incorporating ZEV technology similar to EPA. It would be appropriate for NHTSA to similarly include technology deployment that is consistent with ZEV program compliance in its fleet modeling.

Overall the agencies appear to have overestimated electric vehicle costs in the TAR. The agencies have utilized state-of-the-art tools including the DOE BatPac model on battery costs. However, somehow costs elsewhere in the agencies' calculations appear to have pushed up electric vehicles' incremental costs to still remain above $10,000 in the 2025 timeframe. Based on our examination of detailed engineering cost files for the TAR, we see agency incremental technology costs for 100- and 200-mile BEVs of $11,000 to $14,000 in 2025. We believe the agencies have overestimated these incremental technology costs, as the ICCT's recent analysis for a similar C-class compact car are approximately $3,100 to $7,300, respectively, for the same BEV ranges[24]. We suggest that the agencies re-examine the applicable BEV and PHEV technology costs.

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[23] *German, J., (2015). Hybrid vehicles: Trends in technology development and cost reduction, July 23, 2015. International Council on Clean Transportation. http://www.theicct.org/hybrid-vehicles-trends-technology-development-and-cost-reduction*

[24] *Wolfram, P., Lutsey, N. (2016). Electric Vehicles: Literature review of technology costs and carbon emissions. International Council on Clean Transportation. http://www.theicct.org/lit-review-ev-tech-costs-co2-emissions-2016*

Off cycle technologies

The inclusion of off-cycle technology in the TAR appears to be incomplete. The agencies only reflected relatively small amounts of the off-cycle technology credits, whereas it is well known that the industry is routinely applying for credits that will at least move the industry toward the pre-approved credits of up to 10 g CO_2 per mile and then go further with potential additional approved credits for 2020-2025 compliance. The use of predefined off-cycle credits and the petitions for more approved credits is an obvious indicator that these are low-cost technologies, relative to the test-cycle engine, transmission, and lightweighting efficiency technologies mentioned above. These credits are likely worth at least 15 g CO_2/mile (i.e., including pre-approved and estimation of additional approved credits). Including this likely low-cost, off-cycle credit usage would expand the technology cost horizon across all vehicle classes and reduce the estimated MTE 2022-2025 technology costs. As a result, it would be appropriate for the agencies to estimate these off-cycle technology costs as being less expensive (i.e., in incremental cost per ton, or cost per fuel consumption reduction) than any of the advanced engine, transmission, or hybridization technologies. Even an imperfect estimate of these costs would be appropriate because companies are clearly prioritizing these technologies over more advanced test-cycle efficiency technologies. Inclusion would reduce the compliance costs of achieving 2022-2025 standards.

Off cycle technologies present several broader issues. The vehicle manufacturers have petitioned EPA to streamline the off-cycle credit approval process.[25] Due to the current lack of data on how vehicles are actually operated in the real world, approval of this petition would be counter-productive. In theory, off-cycle credits are a good idea, as they encourage real-world fuel consumption reduction for technologies that are not fully included on the official test cycles. However, real-world benefits only accrue if double-counting is avoided and the amount of the real-world fuel consumption reduction is accurately measured. The problem is that there has not been any systematic study of driving conditions and consumer driving behavior for at least 25 years. This lack of data makes it difficult, if not impossible, to establish generic credits or know if any particular submitted data is truly representative. This provides an incentive for manufacturers to generate real-world data on a biased sample of in-use vehicles, in order to obtain artificially large credits.

The proper solution could be for EPA to launch a collaborative data collection program, in cooperation with the manufacturers and the Department of Energy, to collect real world data representative of national driving behavior and conditions. This data set would allow EPA to establish standardized credits that would apply to all manufacturers and would not be subject to gaming. Surely other groups like the ICCT would collaborate in such as data collection program. But any effort to streamline the off-cycle credit approval process must be contingent upon gathering this type of data.

[25] *Petition for Direct Final Rule with Regard to Various Aspects of the Corporate Average Fuel Economy Program and the Greenhouse Gas Program, Alliance of Automobile Manufacturers and the Association of Global Automakers, June 20, 2016.*

Technology cost implications

The implications of the above technical comments, if incorporated in the agencies' modeling, would be substantial in reducing the estimated technology costs to comply with the 2022-2025 standards. Removing artificial near-term restrictions on technology applicability (e.g., on high-compression ratio engines, transmission technologies, mass reduction) could reduce compliance costs for 2022-2025 regulatory compliance by several hundred dollars per vehicle. Inclusion of new technologies, like e-boost, variable compression ratio, or dynamic cylinder deactivation, for example, and expansion of very cost-effective technologies, like Miller cycle and lightweighting, would expand the technology horizon and further reduce average compliance costs from the agencies' conservative technology estimates.

The inclusion of off-cycle technology costs for up to 10-15 g CO_2 per mile for 2022-2025 model year vehicles would also lower estimated compliance costs, perhaps by several hundred dollars per vehicle. And this would also be more in line with likely auto manufacturing companies' likely approaches to comply with the standards. Although we express reservations above about how the off-cycle credits could continue to be granted, we believe it is correct to include the likely widespread use of the off-cycle credit program in the agencies' evaluation of technology costs to comply with the 2022-2025 standards.

The inclusion of ZEV regulation compliance by NHTSA is appropriate based on automakers' current plans to comply with those regulations, and this would reduce the applicable CAFE compliance costs. We also believe that the agencies should assess how and why their electric vehicle incremental costs appear to be so much higher than other research, as noted above.

In addition, we close by encouraging the agencies to assess the prospects for continued 2026-2030 standards with increasing stringency at 5% lower CO_2 emissions per model year. There appears to be a lot of technology efficiency available, including a lot of advanced combustion technology that is not being deployed in the fleet by many companies. This suggests that the agencies may not be anywhere near their full authority of implementing maximum feasible and technology-forcing standards. Including a forward-looking assessment in a final TAR could help in providing context and longer-term implications of the analysis for future stakeholder discussions. This would also be consistent with efforts in Europe to assess longer-term CO_2 targets. Starting a conversation toward 2030 standards would also be consistent with the agencies' precedent in setting standards with long lead-time of at least 12 years (i.e., setting 2025 standards in 2012). This would also be helpful for the federal agencies to remain engaged in a 2030 discussion, considering California has just adopted new legislation that provide the authority to start working on 2030 climate policies. We encourage the agencies to conduct such analysis with their various tools (e.g., lumped parameter, ALPHA, OMEGA, Volpe) to assess the implications for lower cost 2022-2025 compliance and also the prospects for 2030 technology deployment.