

December 30, 2016

RE: Proposed Determination on the Appropriateness of the Model Year 2022–2025 Light Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation

The International Council on Clean Transportation (ICCT) welcomes the opportunity to provide comments on the *Proposed Determination* of the U.S. Environmental Protection Agency to maintain 2022-2025 standards. 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 in order to benefit public health and mitigate climate change.

We welcome this chance to comment on the U.S. government's efforts to mitigate global climate change and reduce the demand for oil in the transport sector. We commend the U.S. EPA for its continuing efforts to promote a more efficient and lower carbon economy, while being responsive to all stakeholders and relevant data. 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](mailto:john@theicct.org)) and Nic Lutsey ([nic@theicct.org](mailto:nic@theicct.org)).

Best regards,



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International Council on Clean Transportation

**International Council on Clean Transportation comments on the  
*Proposed Determination on the Appropriateness of the Model Year  
2022–2025 Light Duty Vehicle Greenhouse Gas Emissions  
Standards under the Midterm Evaluation***

Public submission to

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

December 30, 2016



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## **I. Overview**

The International Council on Clean Transportation (ICCT) provides these comments to the Proposed Determination on the Appropriateness of the Model Year 2022–2025 Light Duty Vehicle Greenhouse Gas (GHG) Emissions Standards under the Midterm of the U.S. Environmental Protection Agency (EPA).

These comments support the proposed determination of the appropriateness of 2022-2025 standards for light-duty vehicles. The EPA has made a clear case that the GHG standards for 2022-2025 remain appropriate under the terms of the Clean Air Act and Midterm Evaluation. Although there is abundant technical evidence to make the standards more stringent, in the interest of maintaining regulatory certainty for industry investments, we agree that maintaining GHG standards for 2022-2025 is appropriate. Under the present circumstances, when federal and California authorities could modify or leave uncertainty around the 2025 standards, the best course of action is to solidify the 2025 standards as originally adopted.

The agencies have added an immense amount of new data related to technology developments that have occurred since the rulemaking. The new data clarifies how the standards are achievable and at lower cost than projected. This level of technical scrutiny over 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 draft Technical Assessment Report (TAR), its Appendix, the Proposed Determination, and its comprehensive Technical Support Document. This body of work is fully responsive to every relevant question. In addition, among the dozens of state-of-the-art supporting technical reports, most of the key engineering report took the extra steps of expert peer-reviews. This expansive body of research has all been made available well in advance of the TAR and Proposed Determination releases. This has been very helpful for all of those stakeholders that have been 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, the TAR and Proposed Determination analyses are generally accurate and complete, but do not always incorporate the latest technology developments. The massive new body of work from this Midterm Evaluation makes it clear that the greenhouse gas emission standards for 2022-2025 model years are built upon a strong technical foundation and can be met with cost-effective technologies. However, in the comments below, we do note several areas where the U.S. EPA could consider additional technology and cost inputs. Our comments below illustrate that it is easier than original anticipated to meet the 2025 standards as adopted, as the standards (1) can be met with known technologies with reduced costs from what U.S. EPA has indicated, (2) ensure a secure environment for efficiency technology investments, and (3) will aid in the international competitiveness of the U.S. auto industry.

## **II. Technologies to comply are available and low cost**

We are generally very supportive of the technical analysis conducted by the U.S. EPA within the TAR and Proposed Determination. 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 and the Proposed Determination. The agencies have conducted a massive amount 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 also 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. Our comments here are chiefly focused on U.S. EPA and its Proposed Determination, but we refer to the “agencies” more broadly, as the comments are also applicable to the California Air Resources Board and the National Highway Traffic Safety Administration in work on the TAR and their potential upcoming rulemaking analyses.

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 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 working papers. Papers on the following technologies are part of this series (all of the papers have been published, except for the diesel paper which is expected by February 2017):

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

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.<sup>8</sup> The results from FEV's analyses were incorporated into the technology working papers and can also help inform the mid-term evaluation.

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<sup>1</sup> 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>

<sup>2</sup> Aaron Isenstadt and John German (ICCT); Mihai Dorobantu (Eaton); David Boggs (Ricardo); Tom Watson (JCI). *Downsized boosted gasoline engines*, <http://www.theicct.org/downsized-boosted-gasoline-engines>

<sup>3</sup> 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>

<sup>4</sup> 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>

<sup>5</sup> 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 technology development and trends in U.S. passenger vehicles*, December 19, 2016. <http://www.theicct.org/lightweighting-technology-development-and-trends-us-passenger-vehicles>

<sup>6</sup> 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*, October 4, 2016. <http://www.theicct.org/automotive-thermal-management-technology>

<sup>7</sup> *Diesel technology paper is in development and should be published by February 2016.*

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

## 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 already using this on most of their vehicles.<sup>9</sup> 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.<sup>10</sup> Toyota has announced that this technology will be in production soon.

Efficiency improvement estimates in the Proposed Determination for non-hybrid Atkinson Cycle engines with cooled EGR range from 3.4% to 7.7%, depending on vehicle class. These estimates are significantly lower than the estimates in the TAR, which ranged from 6.6% to 10.4%. And both are significantly lower than the estimates in the naturally aspirated technology working paper, which found that Atkinson cycle combined with high compression ratio and cooled EGR improved efficiency by 10% to 15%. These figures are summarized in Table 1.

**Table 1. Fuel consumption reduction of Atkinson cycle, high compression ratio, cooled EGR engine technology**

Vehicle	Proposed Determination vehicle type	TAR	Proposed Determination	ICCT technology report
Small car	LPW_LRL	10.3%	7.7%	12.5%
Standard car	MWP_LRL	7.5%	6.2%	12.5%
Large car	HPW	6.6%	6.9%	12.5%
Crossover	LPW_HRL	10.4%	6.8%	12.5%
Sport utility vehicle	MPW_HRL	7.6%	4.6%	12.5%
Large truck	Truck	8.3%	3.4%	12.5%
Average		8.5%	5.9%	12.5%

*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

<sup>9</sup> 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>

<sup>10</sup> "Toyota claims record gasoline efficiency." Ricardo Quartly Review Q2 2014, p. 4. Accessed June 2016. [http://www.ricardo.com/Documents/RQ%20pdf/RQ%202014/RQ%20Q2%202014/RQ\\_Q2\\_2014\\_English.pdf](http://www.ricardo.com/Documents/RQ%20pdf/RQ%202014/RQ%20Q2%202014/RQ_Q2_2014_English.pdf)

every other revolution of the engine.<sup>11</sup> 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.

The naturally aspirated working paper found 1.5% to 4.0% incremental benefits for DCA over conventional deactivation. For conventional deactivation, the TAR and the Proposed Determination found smaller benefits on 4-cylinder engines than V6/V8. This should not be the case with dynamic cylinder deactivation, which should work just as well on a 4-cylinder, so 3.0% was added to 4-cylinder engines, and 2.5% to V6 and V8 engines.

Variable valve lift (VVL) is needed for dynamic deactivation. The cost estimate for VVL in the naturally aspirated technology report is 110 Euros, or \$121 for a 4-cylinder engine. In addition, the Joint TSD, p 3-81, states that engines equipped with “mechanisms required for cylinder deactivation” would only cost an additional \$32 for NVH improvements. This \$32 has been added to the FEV EU VVL costs. The rest of EPA's cost for conventional cylinder deactivation is not considered, as their costs primarily accounted for finger-follower de-lashing on a fixed block of cylinders (half the cylinders of a V6 or V8), which is not needed for dynamic cylinder deactivation. EPA's cost for conventional cylinder deactivation is based on finger-follower de-lashing on a fixed block of cylinders (half the cylinders of a V6 or V8), plus \$32 for NVH improvements. These figures are summarized in Table 2.

**Table 2. Technology cost and fuel consumption reduction for cylinder deactivation**

	Cost			Fuel consumption reduction
	I4	V6	V8	
Proposed Determination – conventional deactivation	\$88	\$157	\$177	3.5% - 5.8%
ICCT technology report – dynamic deactivation	\$153	\$247	\$274	6.5% - 8.3%

Miller cycle for turbocharged engines. The Proposed Determination applied the additional costs for Atkinson cycle engines to Miller cycle engines: \$93 for I4, \$140 for V6, \$222 for V8. This is not appropriate, as most of the cost of the Atkinson engine in the Proposed Determination was due to increased scavenging to maintain performance and extend the efficiency region. However, for the Miller cycle, this performance function is duplicative of the 24bar turbo system with a Variable Geometry Turbocharger also added in the Proposed Determination to maintain performance for the Miller cycle. Thus, the Atkinson-2 costs are valid for naturally aspirated engines, but should be removed for Miller cycle.

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.

<sup>11</sup> 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](https://www.youtube.com/watch?v=_4AZbbBjqhM). Cecur, Majo, Veiga-Pagliari, D.R. “Dynamic Cylinder Deactivation (D-CDA).” PSA & Eaton. Presented at 24th Aachen Colloquim Automobile and Engine Technology. October 7, 2015.

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 VCR application in a production turbocharged engine in MY2017.<sup>12</sup> The agencies did not appear to explicitly model variable compression ratio technologies that could be quite important in the 2025 fleet.

Direct injection, stoichiometry. FEV EU specifically calculated updated costs for gasoline direct injection.<sup>13</sup> Their cost estimates were \$99 on a 1.0-L I3 turbo DI w/"higher pressure" rail than PFI system, \$150 for 350 bar system on a 0.8-L i3, and \$112 for a 1.4-L I4 w/"higher pressure" rail than PFI system. FEV's costs are scaled to V6 and V8 engines using FEV I3 cost divided by EPA's I3 cost. The technology working paper did not assess GDI efficiency benefits, so there is no change for efficiency. These figures are summarized in Table 3.

**Table 3. Technology cost for direct injection**

	Cost			
	I3	I4	V6	V8
Proposed Determination	\$241	\$241	\$363	\$436
ICCT technology report	\$125	\$112	\$194	\$233

Cooled EGR (gasoline). FEV EU specifically calculated updated costs for gasoline cooled EGR.<sup>14</sup> They calculated a cost of \$116 for inline engines (C-segment 4-cylinder) and \$140 for V engines (D- and E-segment V6). As the Proposed Determination did not include a separate estimate of efficiency for cooled EGR, we are unable to assess cooled EGR efficiency.

**Table 4. Technology cost for cooled EGR**

	Cost	
	Inline	V
Proposed Determination	\$265	\$265
ICCT technology report	\$116	\$140

## 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 has remained constant from the rulemaking to the TAR to the Proposed Determination, even though automakers are deploying greater amounts of mass-reduction technology. The

<sup>12</sup> 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>

<sup>13</sup> 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>

<sup>14</sup> Aaron Isenstadt and John German (ICCT); Mihai Dorobantu (Eaton); David Boggs (Ricardo); Tom Watson (JCI). Downsized boosted gasoline engines, October 28, 2016. <http://www.theicct.org/downsized-boosted-gasoline-engines>

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 5). There are numerous material improvements in development that were not considered in the rule, such as higher strength aluminum,<sup>15</sup> improved joining techniques for mixed materials, third-generation steels with higher strength and enhanced ductility,<sup>16</sup> a new generation of ultra-high strength steel cast components, and metal/plastic hybrid components.<sup>17</sup> These developments are just a sample of the developments discussed in the joint ICCT/supplier technology working paper on lightweighting.

**Table 5. Sample of vehicle mass reductions**

Vehicle model	Model year	Weight reduction (kg)	Weight reduction (%)	Base year
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
Chrysler 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

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. Further, high-strength steel, aluminum, and carbon fiber all have better crash properties than conventional steel, so increased adoption of these materials will improve the safety of the fleet – a factor that has not

<sup>15</sup> 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>

<sup>16</sup> 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/>

<sup>17</sup> 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.

been properly assessed by the agencies. 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%.

We are pleased to see the updated estimates for efficiency improvements due to lightweighting in the Proposed Determination and we completely support this revision. As background, in the analysis for the MYs 2012-2016 final rule, NHTSA and EPA estimated that a 10 percent mass reduction with engine downsizing would result in a 6.5% reduction in fuel consumption while maintaining equivalent vehicle performance (i.e., 0-60 mph time, towing capacity, etc.), consistent with estimates in the 2002 NAS report.

However, in the 2017-25 FRM, both agencies chose to use the effectiveness value for mass reduction from EPA's lumped parameter model to maintain consistency. EPA's lumped parameter model mass reduction effectiveness is based on a simulation model developed by Ricardo, Inc. under contract to EPA. The 2011 Ricardo simulation results show an effectiveness of 5.1 percent for every 10 percent reduction in mass. This value was also used in the TAR.

The ICCT supports EPA's updated estimates in the Proposed Determination (average 6.1% fuel consumption reduction per 10% weight reduction), as we believe the Ricardo simulation model results are not accurate. This is because Ricardo optimized every aspect of the powertrain for the baseline vehicle without weight reduction, but do not do a complete re-optimization of the powertrain after weight reduction was applied. Thus, their simulations underestimate the benefits of weight reduction.

A much better way to estimate the efficiency impacts of weight reduction for fully optimized powertrains is to derive them from the physical equations of motion. There is no theoretical reason why the weight of the vehicle should have a significant impact on the overall efficiency of comparable optimized powertrains. Thus, the appropriate way to estimate the efficiency benefits of lightweighting is to model the reduction in load over the FTP and highway test cycles. Given a specified vehicle (i.e., a vehicle with defined mass, rolling resistance, aerodynamic drag, and accessory load characteristics) and a specified driving cycle, it is possible to precisely calculate the tractive energy required for the vehicle to execute the driving cycle. The ratio of such energy requirements for changes in any of the vehicle specifications—in this case mass—can be taken as a direct indicator of changes in associated fuel consumption (and, by extension, CO<sub>2</sub> emissions). This was done by ICCT for development of post-2020 cost curves for Europe over 6 different vehicle classes.<sup>18</sup> Applying the same methodology to the US test cycles resulted in an average efficiency improvement of 6.3% for a 10% weight reduction.

The improved accuracy of EPA's updated fuel consumption reduction estimates can also be seen by comparing the estimates in the Proposed Determination to Meszler's energy model by class. EPA's estimates track the energy requirements nicely, supporting their revised estimates. Table 6 summarizes these costs and fuel consumption reduction impacts.

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<sup>18</sup> Dan Meszler, John German, Peter Mock, and Anup Bandivadekar (2016). *CO2 reduction technologies for the European car and van fleet, a 2025-2030 assessment: methodology and summary of compliance costs for potential EU CO<sub>2</sub> standards*. <http://www.theicct.org/co2-reduction-technologies-european-car-and-van-fleet-2025-2030-assessment>

**Table 6. Fuel consumption reduction for 10% weight reduction**

Vehicle	Proposed Determination vehicle type	Energy Model example vehicle	TAR	Proposed Determination	Meszler Energy Model
Small car	LPW_LRL	Yaris	5.1%	5.5%	5.7%
Standard car	MWP_LRL	Camry	5.1%	6.3%	6.6%
Large car	HPW	300	5.1%	6.8%	6.8%
Crossover	LPW_HRL	Vue	5.1%	5.8%	6.2%
Sport utility vehicle	MPW_HRL	Grand Caravan	5.1%	6.2%	6.5%
Large truck	TRUCK	F150	5.1%	5.8%	6.2%
Average			5.1%	6.1%	6.3%

## Thermal management, e-boost, and hybrid technology

*Thermal Management.* In the past decade, there has been a proliferation of new devices to control heat and reduce energy losses. More than 60 thermal management technologies are currently in production or development. This heightened pace of development is expected to continue for the next 10 years under regulatory pressure to reduce fuel consumption and carbon dioxide emissions. The Proposed Determination did not specifically address most of these technologies in baseline and projected future vehicles.

Thermal management systems in conventional powertrains are targeted primarily at improving efficiency, thus their primary evaluation metric is their effect on fuel consumption compared with cost. Thermal efficiency gains in the passenger compartments of conventional vehicles will mostly manifest as improved customer satisfaction and marketability.

There are 60-odd new thermal-management systems in development and over half are projected to cost less than \$50 for each 1% reduction in fuel consumption. Passenger cabin technologies tend to cost more, but their primary benefit is in customer comfort, which adds additional value beyond the fuel savings. Thermal management gains can yield declines in fuel consumption on the order of 2% to 7.5% over the next 10 years, depending on a power train's base thermal-management features.<sup>19</sup> Note that the primary benefit of most thermal management systems are off-cycle, thus, the proper way to account for these benefits is to apply them to off-cycle credits.

*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.<sup>20</sup> 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 gasoline downsized boosted working paper found that total efficiency benefits are likely to be about 5% at a cost of about \$400. The

<sup>19</sup> Sean Osborne, Dr. Joel Kopinsky, Sarah Norton, Andy Sutherland, David Lancaster, Erika Nielsen, Aaron Isenstadt, John German, *Automotive Thermal Management Technology (ICCT: Washington DC, 2016)*. <http://www.theicct.org/automotive-thermal-management-technology>

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

first E-boost system application is in production on the 2017 Audi QS7.<sup>21</sup> 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, the correspondingly smaller battery, and staying below the 60v lethal threshold greatly reduce the cost for this level of hybridization.<sup>22</sup> 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 added analyses of 48v hybrid systems, but we recommend that the agencies investigate the synergies between 48v hybrids and e-boost systems.

The Proposed Determination has one cost for all 48v hybrids and the benefits go down as vehicle size increases. Thus, it is clear that the Proposed Determination is using the same 48v system on each vehicle. The turbo-downsized working paper estimated 10-15% benefit for 48v hybrids, with 12.5% as mid-range. To apply the same 48v system to each vehicle class, as was done in the Proposed Determination, the Proposed Determination percent improvements were ratioed by 12.5% divided by the average EPA benefit for the different classes without the truck class (which the turbo-downsized working paper did not consider). This results in 37% greater efficiency benefits for 48v hybrids, applied to each vehicle class. In EPA's Lumped Parameter Model (LPM) for the Proposed Determination, HEVs (including 48v hybrids) are penalized with a 48 percentage point increase in transmission losses. The reason for this is not known, but may help to explain the difference in the efficiency benefits. The cost estimates for 48v hybrids in the turbo-downsized working paper ranged from \$600 to \$1,000, very similar to the cost estimate of \$766 in the Proposed Determination. Table 7 summarizes these costs and fuel consumption reduction impacts.

**Table 7. Technology cost and fuel consumption reduction for 48-volt hybrid**

	Cost	Fuel consumption reduction
Proposed Determination	\$766	7.0%-9.5%
ICCT technology report	\$600 - \$1,000	9.6%-13.1%

*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

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

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

hybrids.<sup>23</sup> 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<sub>2</sub> 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, when they do their associated rulemaking, 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. The agencies have utilized state-of-the-art tools including the DOE BatPac model on battery costs. Yet their costs calculations have erroneously pushed up electric vehicles' incremental costs to be approximately \$10,000 per vehicle, in the 2025 timeframe. Based on our examination of detailed engineering cost files, we see U.S. EPA incremental technology costs for 100- and 200-mile BEVs of \$9,000 to over \$11,000 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<sup>24</sup>. We suggest that the agencies re-examine the applicable BEV and PHEV technology costs, including the battery, non-battery, other powertrain cost factors, and the associated indirect costs for the technology.

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<sup>23</sup> 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>

<sup>24</sup> 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>

## Response on industry technology assessment

The ICCT completely supports the assessment in the Proposed Determination of Novation's study<sup>25</sup> for the Alliance of Automobile Manufacturers. While the Novation study clearly defined what they did and didn't do, Novation did not actually evaluate technology potential. Instead, they duplicated the technology packages in the 2017–2025 rulemaking and compared them to current vehicles using these technologies. As a result, the study used outdated technology assumptions and implicitly assumed there would be no technology innovations after 2014.

Novation's technology assessments did not incorporate projected improvements in each technology from 2014 to 2025, as EPA and NHTSA did in the rulemaking. Instead, Novation started with the 2014 distribution of engine efficiencies and assumed that the average efficiency of each technology in 2025 would be the same as the 90% percentile efficiency in 2014. The Novation study specifically states, "In the timeframe of the MYs 2012-2016 and MYs 2017-2025 rulemaking, however, it is not likely that the sales-weighted fleet performance will exceed the current boundaries established by the best in class vehicles utilizing many of the technologies listed above." This implicitly assumes there will be no technology innovations beyond what was already incorporated into some vehicles in 2014. Given the history of constant technology innovation, this assumption is completely unjustified. It is essentially the same as saying that the iPhone6 was the best smart phone in the market in 2014, so in 2025 the average smart phone will be the same as the iPhone6. Applying this methodology to vehicle technology is no better than applying it to smart phones.

As a specific example of an unfounded assumption, Novation's study stated: "the current compression ignition (24-29 bar maximum BMEP diesel) can be used as a representative proxy as it is unlikely even an advanced SI package will exceed the current CI efficiency boundary." It is accurate that 2025 SI (spark ignited, or gasoline) engines must exceed the efficiency of current CI (compression ignition, or diesel) engines. But any competent analysis of upcoming powertrain technology (like those referenced by US EPA in its analysis) finds that 2025 gasoline engine powertrains will exceed current diesel powertrain efficiency. Novation's assumption makes for a good sound bite, but it has no analytical basis.

To illustrate the shortcomings of Novation's approach, Novation's found that the 90th percentile efficiency for naturally aspirated engines, which they used as the average efficiency for 2025 naturally aspirated engine, was 22.8% (with high-spread transmission without stop/start). However, Novation's own data showed that the 2014 Mazda SkyActiv engine already had an efficiency of 25.1%. This is 10% higher than Novation's 2025 estimate — and almost as high as the average 2014 diesel engine (26%) — with 11 years of improvements yet to come. Another flaw is that Novation simply duplicated the technology set that was used in the rulemaking. As this technology set is 5 years old, Novation implicitly froze the level of innovation at the 2012 level. Not only did Novation ignore all future technology innovation, it also ignored all technology innovation that has occurred in the last 5 years. Overall, there is some interesting information in the Novation study on the efficiency of the 2014 fleet, but it uses old data (5-year old technology sets) and assumption that there are no improvements beyond what was in the better vehicles in the 2014 fleet makes it applicability limited. The EPA analysis and the technical studies that

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<sup>25</sup> *Novation Analytics. Final Report - Technology Effectiveness – Phase I: Fleet-Level Assessment (version 1.1), prepared for: Alliance of Automobile Manufacturers Association of Global Automakers, October 19, 2015. <http://www.autoalliance.org/cape/cape-research-reports>*

underpin its findings utilize the most rigorous state-of-the-art technology simulation and teardown methods; these are in stark contrast to Novation’s backward-looking analysis.

### 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 full inclusion of off-cycle technology for 2022-2025 model year vehicles would also likely lower estimated compliance costs. The inclusion of ZEV regulation compliance by EPA is appropriate based on automakers’ current plans to comply with those regulations.

Table 8 summarizes the efficiency technology fuel consumption benefit and cost assessments. The benefits are in percentage fuel consumption per mile reduction, and the costs are the average cost increment per vehicle. These are a selection of the technology inputs that underpin the Proposed Determination, and comparable numbers from ICCT's analyses of recent vehicle efficiency technology developments and trends. Based on our assessment of these technologies, it is already abundantly clear that the 2025 standards will be significantly easier and cheaper to meet than predicted in the Proposed Determination. This indicates the agencies could have set more stringent standards and still met the same cost-effectiveness criteria. It also shows that EPA has been very conservative in their technology assumptions.

**Table 8. Technology cost and fuel consumption reduction for cylinder deactivation**

	Fuel consumption benefits (average) <sup>a</sup>		Cost (average) <sup>b</sup>	
	Proposed Determination	ICCT technology reports	Proposed Determination	ICCT technology reports
Cylinder Deactivation	4.4%		\$125	
Dynamic cylinder deactivation		7.1%		\$204
Direct Injection			\$313	\$165
Cooled EGR			\$265	\$128
E-boost	Not included	5.0%	Not included	\$400
48v Hybrid	8.8%	12.0%	\$765	\$600 - \$1,000
Atkinson Cycle	5.9%	12.5%		
Miller Cycle (turbo)		Varies <sup>c</sup>		\$129 lower
Thermal Management		5%		\$250
Lightweighting (2025 fleet average)	7%	15%		
Electric vehicle			\$9,000-\$11,000	\$3,100-\$7,300

<sup>a</sup> Average for 6 different vehicle classes

<sup>b</sup> Weighted 50% 4-cylinder, 35% V6, 15% V8 (except as noted)

<sup>c</sup> Includes Atkinson Cycle, 24bar turbocharging, cooled EGR, and engine downsizing

<sup>d</sup> Fleet average

### III. Regulatory certainty secures industry investments

Although there is sufficient evidence to develop even more stringent standards, in the interest of maintaining regulatory certainty for industry investments, we believe that maintaining EPA's adopted GHG standards for 2022-2025 is appropriate. Maintaining 2022-2025 regulatory stringency would assure a stable regulatory environment. Any new uncertainty about the federal 2025 standards would provoke uncertainty with California and other states (representing as much as one third of the U.S. market) continuing with adopted 2025 regulatory standards.

Destabilization of the 2025 standards would put grave uncertainty on the returns on the billion-dollar investments that automakers and suppliers have made. Table 3 highlights a selection of industry investments in the U.S. related to automobile efficiency technology<sup>26</sup>. As shown, the investments represent many thousands of high-tech manufacturing jobs and billions of dollars in investments. The success and sustainability of such technology investments depends on a stable regulatory environment. There is a clear connection between the standards and investments that directly contribute to American jobs. Maintaining the standards would protect high-technology manufacturing investments in efficiency technologies, whereas weakening or uncertainty about the standards jeopardizes such investments.

ICCT completely supports EPA's assessment in the Proposed Determination of the jobs study by the Center for Automotive Research (CAR). ICCT recently wrote a detailed critique<sup>27</sup>, discussing the multiple problems with this study. In short, the whole report rests on a false premise about the costs of meeting the standards. CAR ignored the dozens of recent state-of-the-art technology analyses and, instead, the report relies on costs from a twenty-five-year-old retail-price manipulation strategy. A 1991 study by David Greene<sup>28</sup> found that automakers could improve their CAFE fuel economy level by increasing the sales price of less fuel efficient models while simultaneously decreasing the price of more fuel efficient models. Greene concluded that this pricing scheme is effective in the short-run for fuel economy improvements of *up to* 1 mpg, and would cost \$100–\$200 (in 1985 dollars). But, Greene also found, for fuel economy improvements greater than 1 mpg, pricing out less-efficient vehicles generates increasing losses for automakers and improved technology and design changes are by far the more cost-effective solution for long-term, large fuel economy improvements. CAR ignored Greene's findings on mpg changes of more than 1 mpg and applied the retail-price manipulation results to the 2025 standards. Further, CAR ignored the economy-wide jobs created by reduced spending on fuel after the first 3 years of ownership.

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<sup>26</sup> Lutsey, N. (2012). *Regulatory and technology lead-time: The case of US automobile greenhouse gas emission standards*. *Transport Policy*. 21: 179-190. <http://www.sciencedirect.com/science/article/pii/S0967070X12000522>

<sup>27</sup> Isenstadt, A. (2016). *The latest paper by the Center for Automotive Research is not what it thinks it is*. <http://www.theicct.org/blogs/staff/latest-paper-by-CAR-is-not-what-it-thinks-it-is>

<sup>28</sup> Greene, D.L., (1991). *Short-run pricing strategies to increase corporate average fuel economy* <http://onlinelibrary.wiley.com/doi/10.1111/j.1465-7295.1991.tb01256.x/abstract>

**Table 9. Auto industry investment and job growth related to efficiency technologies**

Company	Technology	Location	Jobs	Investment
Ford	Efficient engines (EcoBoost)	Cleveland, Ohio	250	\$55 million
GM	Efficient engines (Ecotec)	Tonawanda, New York	350	\$825 million
GM	Efficient engines (Ecotec)	Spring Hill, Tennessee	483	\$483 million
GM	Engine, transm., stamping	Lordstown, Ohio	1200	\$500 million
Hyundai	Efficient engines	Montgomery, Alabama	522	\$270 million
Chrysler	Engine (FIRE)	Dundee, Michigan	150	\$179 million
ZF	Transmissions	Laurens County, South Carolina	900	\$350 million
Toyota	Transmission, aluminum parts	Buffalo, West Virginia; Jackson, Tenn.; Troy, Missouri	40	\$64 million
GM	Transmission, electric motors	White Marsh, Maryland	200	\$246 million
Fiat-Chrysler, ZF	Transmission (8-speed)	Kokomo, Indiana		\$300 million
Bosch	Gasoline injectors, diesels	Charleston, South Carolina	300	\$125 million
Michelin	Tires	South Carolina	100	\$350 million
Lenawee Stamping	Metal stamping	Tecumseh, Michigan	140	
Tenneco Autom.	Emission control	Michigan	185	\$15.6 million
Gestamp	Stamping	Chattanooga, Tennessee	230	\$90 million
Gestamp	Steel components	Mason, Michigan	348	\$74 million
ThyssenKrupp	Steel	Mount Vernon, Alabama	2700	\$3700 million
Nanshan	Aluminum extrusion parts	Lafayette, Indiana	200	\$100 million
Magna	Composite parts	North Carolina	327	\$10 million
BMW, SGL	Carbon fiber parts	Moses Lake, Washington	80	\$100 million
Faurecia, Ford	Plastic parts	US and Mexico	350	
TRW, Ford	Electric power steering	Marion, Virg; Rogersville, Tenn.	115	\$55 million
Continental, Ford	Engine, brakes, tires, access.	Henderson, North Carolina	60	
Nexteer Autom.	Driveline, steering	Saginaw, Michigan		\$431 million
Denso	Aluminum parts	Hopkinsville, Kentucky	80	\$4.2 million
NHK	Suspension parts	Bowling Green, Kentucky	100	\$20 million
Ford	Fuel-efficient, hybrid, electric vehicles	Louisville, Kentucky	1800 (7000)	\$600 million (\$1000 million)
V-Vehicle	Hybrid vehicles	Monroe, Louisiana	1400	\$248 million
GM	Battery, drivetrain, engine, generator	Brownstown, Hamtramck, Warren, Bay City, Grand Blanc, and Flint, Michigan	1000+	\$700 million
Nissan	Electric vehicles, components	Smyrna, Tennessee	1300	\$1700 million
Magna	Electric drive components	Michigan	500	\$49 million
Ford	Batteries, transaxles	Rawsonville, Sterling Heights, Michigan	170	\$135 million
Toda America	Batteries	Battle Creek, Michigan	60	\$35 million
JC-Saft	Batteries	Holland, Michigan	550	\$299 million
LG Chem	Batteries	Holland, Michigan	400	\$151 million
Fortu PowerCell	Batteries	Muskegon Township, Michigan	1971	\$625 million
Bannon Autom.	Electric vehicles	Onondaga County, New York	250	\$26.6 million
A123	Batteries	Ann Arbor	5000	\$600 million
Magna	Batteries, drivetrain, power electronics, flexible foam	Auburn Hills, Troy, Shelby Township, Lansing, Michigan	500	\$50 million
Toyota, Tesla	Electric vehicles	Fremont, California	1000	\$50 million

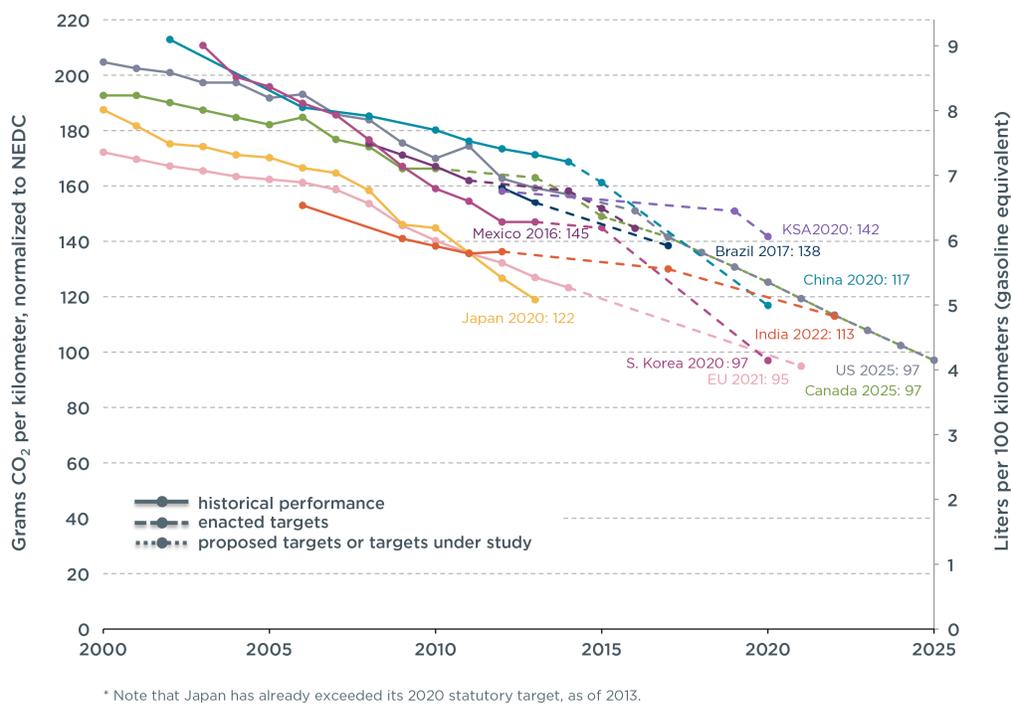
Source: Lutsey, N. (2012). Regulatory and technology lead-time: The case of US automobile greenhouse gas emission standards. *Transport Policy*, 21: 179-190. <http://www.sciencedirect.com/science/article/pii/S0967070X12000522>

Furthermore and relatedly we would encourage the federal agencies to assess the prospects for continued 2026-2030 standards with increasing stringency at 5% lower CO<sub>2</sub> emissions and fuel consumption per model year. There are clearly a lot of available efficiency technologies, including a lot of advanced combustion technology that is not being deployed in the fleet by many companies. The agencies are not yet anywhere near their full authority of implementing maximum feasible and technology-forcing standards. Starting analysis toward 2030 standards would also be consistent with the agencies' precedent in setting standards with long lead-time of 12-13 years (i.e., setting 2025 standards in 2012). This would also be helpful for the federal agencies to remain engaged in a 2030 discussion, because California appears likely to begin work on 2030 climate policies that are also in the national interest of encouraging petroleum

reduction and energy independence. This would also be consistent with efforts in Europe to assess longer-term 2030 CO<sub>2</sub> targets to increase lead-time to support industry investment and international competitiveness.

#### IV. National standards support competition in a global market

The U.S. fuel economy and greenhouse gas regulations have the U.S. fleet headed in the same direction as most other major world automobile markets, reducing per-mile carbon dioxide (CO<sub>2</sub>) emissions at approximately 3% per year. About 80% of world automobile sales are regulated to increase their efficiency and reduce carbon emissions. Like the U.S. standards, all other standards around the world are indexed to vehicle size (or mass), and therefore require that efficiency technologies like those described above are deployed in the fleet. Figure 1 shows the progression of global efficiency standards in major world car markets.<sup>29</sup> In the U.S. case, industry has consistently over-complied with 2012-2015 standards while the industry overall achieved U.S. vehicle sales at their all-time highs, and with most companies producing high profits. Compliance with the standards helps ensure that U.S.-based companies embrace leading technology and remain internationally competitive elsewhere around the world. Conversely, the weakening standards make it more difficult for U.S.-based companies to compete in the major automobile markets around the world, including Europe and China, which have increasingly stringent efficiency standards.



**Figure 1. Passenger car efficiency standard CO<sub>2</sub> emissions**

<sup>29</sup> International Council on Clean Transportation, 2015. Global passenger vehicle standards. <http://www.theicct.org/info-tools/global-passenger-vehicle-standards>

## V. Summary

The EPA has comprehensively and satisfactorily considered the relevant factors as required per the terms of Clean Air Act section 202(a) and Midterm Evaluation in making its proposed determination to maintain model year 2022-2025 standards. In summary we conclude with the following points in favor of finalizing the determination –

- Considering the availability and effectiveness of technology, and the appropriate lead-time for introduction of technology, maintaining 2022-2025 standards as adopted is the wisest course of action. The rapid development of powertrain improvements to gasoline vehicles in particular continues to provide ever-abundant opportunities for manufacturers to predominantly comply with incremental internal combustion technology. Fuel-efficient vehicle technologies are available and only need to partially penetrate the fleet to comply with the 2025 standards, further indicating that the regulation's lead-time was appropriately gradual for industry compliance by deploying known technologies.
- The cost of the standards (an additional \$875 per vehicle, per EPA's latest estimation) on the producers and the purchasers of new motor vehicles make for a highly cost-effective regulation, with three time higher benefits than costs.
- The feasibility and practicability of the standards has clearly been established by EPA's state-of-the-art technology, compliance, and economic modeling assessments and peer-reviewed research. The record goes further by clearly indicating the standards could be set more stringently by greater deployment of known cost-effective technologies.
- The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers require that EPA maintain the standards. The EPA analysis shows the fuel savings are several times greater than the vehicle technology costs, even when lower fuel prices are included. The analysis also indicates that the standards save the U.S. over 1.2 billion barrels over the regulated vehicle lifetimes, meaning the consumer savings aggregate to massive reduction in oil use nationally. Underscoring the importance of at least maintaining the 2025 standards, recent trends toward higher vehicle activity and larger vehicles suggest that EPA would need to make more stringent standards to achieve the originally proposed benefits to oil consumption and emissions. Any relaxation of standards would further jeopardize the U.S. energy security and increase American consumers' fuel expenditures.
- The impacts of the standards on the automobile industry have been thoroughly assessed. The auto industry has consistently over-complied with 2012-2015 standards while achieving near-all-time U.S. automobile sales and profit growth. Beyond the agency analysis, from an international perspective, the automobile industry's compliance with the standards will help ensure they embrace leading technology and remain internationally competitive. Conversely, weakening standards would make it more difficult for U.S.-based companies to compete in the major automobile markets around the world like Europe and China, which have increasingly stringent efficiency standards.
- EPA has appropriately considered all applicable aspects of light-duty vehicle sales, the projected fleet mix, and consumer acceptance. The continuation of footprint-indexed greenhouse gas standards that are based on vehicle fleet mix appropriately accommodates the changing fleet mix due to market shifts, as well as from the changing costs for gasoline and other fuels. Accounting for market shifts and emerging technologies that have high consumer acceptance, EPA has rigorously considered the regulation's impact on consumer vehicle payback periods.
- EPA has appropriately found that the regulation can be met with predominantly with incremental combustion technology (i.e., 95% of new vehicles in 2025 are not plug-in

electric technology). To the modest extent that electric vehicles will be deployed, EPA has considered the necessary charging infrastructure.

- The impacts of the standards on automobile safety have been assessed by the agencies. Efficiency technologies, including lightweighting technology, continue to be deployed in ever-safer vehicles, as more detailed computer tools to assess every aspect of vehicle for efficiency simultaneously result in more crashworthy vehicle designs. State-of-the-art automaker lightweight vehicle offerings that are already in the fleet demonstrate that the fleet can still see further weight reduction without adverse impacts on safety.
- The EPA has considered the impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program. Appropriately, EPA has provided ample auto industry flexibilities through technology credits, emission trading, smaller volume company provisions, and footprint indexed standards to accommodate fleet shifts. These EPA provisions greatly assist automobile industry compliance. Based on the well-designed EPA flexibilities, any further improvement toward a harmonized one national program would best be addressed with adjustments in the Corporate Average Fuel Economy, matching NHTSA's program with EPA's improved manufacturer flexibilities. Appropriately, EPA has included California's Zero-Emission Vehicle program compliance in their compliance scenarios, as automakers are expected to comply with ZEV program as part of their national fleet deployment. Locking in the US EPA greenhouse gas program through model year 2025 provides the best chance at keeping one consistent federal-and-California regulatory program.
- Another relevant factor is that companies have made major billion-dollar technology investments that are predicated upon a stable regulatory environment. Beyond the environmental and energy independence benefits, these high-tech investments directly contribute to American manufacturing jobs. Any weakening of the standards would directly undercut vehicle technology investments. Furthermore, decreased U.S. investments in efficiency technology would put U.S.-based companies in a weaker position to deploy their products in the largest global markets, like Europe and China.