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October 16, 2023

COMMENTS OF MECA CLEAN MOBILITY
ON THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION'S PROPOSED CORPORATE AVERAGE FUEL ECONOMY STANDARDS FOR PASSENGER CARS AND LIGHT TRUCKS FOR MODEL YEARS 2027-2032 AND FUEL EFFICIENCY STANDARDS FOR HEAVY-DUTY PICKUP TRUCKS AND VANS FOR MODEL YEARS 2030-2035
NHTSA-2023-0022

MECA Clean Mobility (MECA) is pleased to provide comments in support of the National Highway Traffic Safety Administration's (NHTSA) Proposed Corporate Average Fuel Economy (CAFE) Standards for Passenger Cars and Light Trucks for Model Years 2027-2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030-2035. As fully electric options continue to increase in the market and become more affordable for consumers purchasing light- and medium-duty vehicles, developments continue in hybrid and plug-in hybrid electric vehicles as well as several engine efficiency technologies. MECA believes an important opportunity exists for performance-based standards to continue to cost effectively improve fuel economy in all segments of the light- and medium duty fleets through the application of advanced internal combustion engine and electrified powertrain system technologies. We strongly support alignment between NHTSA and EPA on fuel economy and GHG regulations, as has occurred on previous standard setting regulations that affect the same vehicle sectors.

MECA is a non-profit association of the world's leading manufacturers of technologies for clean mobility. Our members have nearly 50 years of experience and a proven track record in developing and manufacturing emission control, engine efficiency, battery materials, power electronics, fuel cells as well as electric propulsion technology for a wide variety of on-road and off-road vehicles and equipment in all world markets. Our industry has played an important role in the efficiency and emissions success story associated with light-, medium- and heavy-duty vehicles in the United States, and has continually supported efforts to develop innovative, technology advancing, emission reduction and fuel efficiency advancement programs to simultaneously improve vehicle fuel economy and ambient and local urban air quality.

MECA members represent over 70,000 of the nearly 300,000 North American jobs building the clean mobility technologies that improve the fuel economy, reduce emissions and transition on-road and non-road vehicles to zero tailpipe emissions. These jobs are located in nearly every state in the United States – the top 10 states being Michigan, Texas, Illinois, Virginia, New York, Indiana, North Carolina, Ohio, Pennsylvania, and South Carolina. The mobile source emission control industry has generated hundreds of billions of dollars in U.S. economic activity since 1975 and continues to grow and add more jobs in response to environmental regulations. Emission control, engine efficiency and electric technology manufacturers invest billions of dollars each year in developing the technologies that reduce emissions from mobile sources. In fact, automotive technology suppliers account for approximately 40% of the auto R&D conducted in the U.S. each year[1].

In order to simultaneously meet future NHTSA fuel economy standards alongside EPA's criteria and GHG emission standards, several technology pathways are needed and available through a combination of advanced propulsion systems. These include full electrification, hydrogen fuel cell electric vehicles, as well as electrified powertrains with engines employing advanced combustion components such as turbochargers, EGR systems, cylinder deactivation, high pressure fuel injection, exhaust emission control catalysts, substrates and evaporative control system architectures. Finalizing the proposed CAFE and heavy-duty fuel efficiency regulatory provisions will provide certainty to technology suppliers and their OEM customers who continue to invest billions of dollars each year in developing the technologies to reduce mobile source fuel consumption and CO_2 emissions to significantly advance US clean transportation and environmental goals.

Summary

MECA supports NHTSA's proposed alternative with some modifications, which would provide more regulatory certainty. Our comments for NHTSA's consideration are summarized here and explained in greater detail in the text that follows:

1. NHTSA should document areas of alignment and misalignment between the CAFE standards and EPA's proposed Light- and Medium-Duty Vehicle Regulation.
2. NHTSA should clearly articulate the effect of DOE's proposed petroleum equivalency factor revision on compliance with NHTSA's proposed standards, under the assumption that automakers will be fully compliant with EPA's proposed Light- and Medium-Duty Vehicle Regulation.
3. NHTSA should include a non-zero fuel efficiency value for BEV HDPUV compliance.
4. NHTSA should continue using SAE J2841 for PHEV utility factor calculations and consider conducting a prospective analysis of appropriate PHEV utility factors based on more recent PHEV models with longer all electric range likely to result in a shift

[1] Motor & Equipment Manufacturers Association, Moving America Forward (2013), https://www.mema.org/resource/2013-economic-impact-study-moving-america-forward

to greater electric operation. PHEVs with all electric range greater than 50 miles should be allowed to claim higher utility factors.

5. Advanced technology credit multipliers for PHEV, BEV and FCEV HDPUVs should end before MY 2027.
6. MECA supports NHTSA retaining off-cycle FCIV for the CAFE Program (light-duty vehicles) and off-cycle credits for heavy-duty pickups and vans since these provide real-world emission benefits.
7. MECA supports inclusion of the role of battery critical materials in NHTSA's rulemaking analysis.
8. NHTSA should work with other agencies, like the Joint Office on Energy and Transportation, in setting minimum charger efficiency standards to ensure that infrastructure funds are spent on chargers with the most efficient utilization of electric power.
9. MECA appreciates NHTSA's technology neutral approach to fuel economy regulation. We have summarized several technologies that improve the efficiency of vehicles.

NHTSA should document areas of alignment and misalignment between the CAFE standards and EPA's proposed Light- and Medium-Duty Vehicle Regulation.

MECA would like to stress the importance of alignment of regulatory standards with EPA for light- and medium-duty vehicles (heavy-duty pick-ups and vans in NHTSA's rule). For the two most recent fuel economy regulations (prior to SAFE) that spanned MY 2012 through 2025, EPA and NHTSA issued joint rulemakings to "implement a strong and coordinated Federal greenhouse gas (GHG) and fuel economy program for vehicles, referred to as the National Program." The agencies stated that this approach would deliver additional benefits, cost savings and administrative efficiencies that would be unlikely if a less coordinated approach had been pursued. In addition, a goal of the National Program was to allow automakers to produce and sell a single fleet across the U.S. in order to minimize compliance costs.[2]

Additionally, NHTSA and EPA noted in previous joint regulatory efforts that "the National Program is both needed and possible because the relationship between improving fuel economy and reducing CO_2 tailpipe emissions is a very direct and close one." MECA agrees with the agencies' conclusion that a single pool of technologies can simultaneously reduce fuel consumption and CO_2 emissions. However, we believe that full lifecycle, including vehicle production, fuel production, fuel use and recycling, should be considered when evaluating compliance with fuel economy and CO_2 requirements. Therefore, given NHTSA and EPA have issued separate rulemakings for GHG and fuel economy, respectively, for MY 2027-2032 light-duty vehicles and MY 2030-2035 heavy-

[2] https://www.govinfo.gov/content/pkg/FR-2010-05-07/pdf/2010-8159.pdf

duty pickups and vans, we request NHTSA spend additional effort to document in the final rule how the regulations are aligned and where they are not aligned.

NHTSA should clearly articulate the effect of DOE's proposed petroleum equivalency factor revision on compliance with NHTSA's proposed standards, under the assumption that automakers will be fully compliant with EPA's proposed Light- and Medium-Duty Vehicle Regulation.

MECA supports DOE's proposed revision of the petroleum equivalency factor (PEF) as it more accurately reflects the equivalent fuel economy of electric vehicles compared to those fueled by gasoline. Furthermore, we support NHTSA's approach of determining compliance with fuel economy standards through a data driven technology neutral approach. NHTSA's proposal notes that its regulatory analysis considers the proposed lower PEF of 23,160 Wh/gal as well as a sensitivity analysis that considers the current PEF of 82,049 Wh/gal. Unfortunately, EPA does not consider lifecycle emissions for compliance with greenhouse gas emission standards and designates battery electric vehicles as emitting zero CO_2. Thus, EPA's standards provide greater weight to battery electric vehicles in compliance compared to NHTSA's standards.

This approach results in the potential for regulated parties being unable to meet both NHTSA and EPA compliance requirements by utilizing the same fleet of vehicles. If compliance with EPA GHG standards leads to financial penalties to comply with NHTSA fuel economy standards, there would be less funds available for investment in technology research and development as well as workforce training. These are critical investments during this transportation transition and reductions in them will weaken US competitiveness and reduce jobs. Since these standards were formerly set in a joint rulemaking, we request NHTSA analyze the impact of separate regulations, particularly on compliance flexibility and the potential for CAFE and fuel economy penalties to be used as a compliance mechanism.

NHTSA should include a non-zero fuel efficiency value for BEV HDPUV compliance.

Efficiency incentives and regulations have historically driven vehicle manufacturers and technology suppliers to continue to innovate and develop better materials, components, and vehicle systems to reduce energy demand, operating costs and related emissions of vehicles. Electric vehicle efficiency does not provide large benefits at today's EV sales penetration rates. However, if electric vehicle sales meet EPA and NHTSA projections, they will make up a much larger fraction of the light- and medium-duty fleets. Therefore, small improvements in efficiency will result in large reductions in grid demand.

Analogous to the use of a petroleum equivalency factor for the CAFE Program, we suggest NHTSA assign a non-zero fuel economy equivalent to BEV and the electric operation of PHEV for HDPUV. Despite these vehicles not using petroleum for operation, they will require energy to operate, which will lead to shifts in energy sources as electric vehicle penetration increases. To drive future U.S. technology leadership and incentivize efficiency improvements in all vehicles, NHTSA's treatment of HDPUVs for the purpose of compliance should incorporate an energy use per mileage or work performed. This is particularly important as the sales volumes of electric and fuel cell vehicles increase, and there are no standards to ensure continued improvements in energy efficiency.

MECA members are commercializing components for electric and hydrogen fuel cell vehicles. These products include battery materials for the manufacture of both cathode and anodes utilizing unique macrostructure and composite formulations to improve efficiency and energy density. Fuel cell membranes designed with a catalytic surface improve the efficiency of hydrogen ionization. Electric component manufacturers use state of the art transistor materials in their motors and power electronics that operate at higher voltages and temperatures thus requiring simpler cooling strategies. These next generation component designs reduce switching losses and improve electric efficiency of the system architecture in electric powertrains. Component suppliers are also integrating the motor, inverter and transmission into electric drive units to simplify the thermal management of the electric components and ease integration into vehicles.

As demonstrated for combustion vehicles over the past 50 years, the market can not always be relied upon to drive innovation towards conservation of critical resources and energy security by improving the efficiency of vehicles. This has led agencies to set fuel efficiency and GHG standards. There is a significant disparity in the electric efficiency between similarly sized passenger electric vehicles today, as shown in Table 1. Given the requirement that compliance with CAFE include the PEF, we believe there will be incentive to improve light-duty BEV efficiency. However, absent an energy equivalent standard for HDPUVs, we expect minimal incentive to provide more efficiency vehicles in that sector.

Table 1. Comparison of Energy Efficiency of BEV and PHEV Models

Tesla Model Y AWD EV Battery Pack: 75 kWh Range: 279 miles **Efficiency: 3.6 miles/kWh**	**Volvo XC40 Recharge Twin EV** Battery Pack: 75 kWh Range: 223 miles **Efficiency: 2.6 miles/kWh**
Toyota RAV4 Prime PHEV Battery Pack: 18.1 kWh Range: 42 miles EV; 600 miles total **Efficiency: 2.8 miles/kWh electric**	**Land Rover Range Rover Sport PHEV** Battery Pack: 12 kWh Range: 19 miles EV; 480 miles total **Efficiency: 1.25 miles/kWh electric**
2022 Ford F-150 Lightning EV Battery Pack: 98 or 131 kWh Range: 230 or 320 miles **Efficiency (estimated): 2 miles/kWh**	**GMC Hummer EV** Battery Pack: 212.7 kWh Range: 329 miles **Efficiency: 1.55 miles/kWh**

NHTSA should continue using SAE J2841 for PHEV utility factor calculations and consider conducting a prospective analysis of appropriate PHEV utility factors based on more recent PHEV models with longer all electric range likely to result in a shift to greater electric operation. PHEVs with all electric range greater than 50 miles should be allowed to claim higher utility factors.

PHEVs will continue to be an important fuel saving technology because they can integrate and optimize the best of combustion and electric technologies to increase vehicle efficiency and facilitate the transition to fully zero tailpipe emissions vehicles. This will be particularly important as the charging infrastructure and supply chains develop that are necessary for battery electric vehicle adoption at the rates projected in the proposal. PHEVs can provide consumers confidence in electric vehicle technology while alleviating range anxiety for those who drive long distances.

Similar to previous technology analyses prepared to support future rulemakings, MECA requests that NHTSA conduct a prospective analysis of utility factors of PHEVs based on the direction of the technologies being released into the marketplace today as well as announcements of future releases. Of particular note, we disagree with EPA's proposal to adjust utility factors down based on data from older technology PHEVs with limited all electric ranges. Given SAE J2841[3] definitions of utility factors were last revised in 2010, we believe a future definition of utility factors should be coordinated with SAE and be based on technologies expected in the marketplace from 2027 onwards.

While NHTSA does not have minimum range requirements for PHEVs to comply with CAFE and fuel efficiency requirements, like those included in CARB ACC II, MECA believes that these requirements along with the market demands will drive PHEVs with longer all electric ranges. In fact, VW recently announced a PHEV Tiguan SUV available for MY 2025 with an all-electric range of 62 miles.[4] These advancements, in combination with build out of charging infrastructure, supported by the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA) funding, will provide consumers with easier access to charge PHEVs and enable them to drive more miles on electricity rather than petroleum. As a result, future fleet utility factors would increase rather than decrease. MECA suggests that NHTSA consider these developments, including studying the correlation between fleet utility factor and workplace charger availability, and not base utility factors on older PHEV technology. At a minimum, NHTSA should not reduce PHEV utility factors below those in SAE J2841. Finally, MECA suggests that NHTSA consider scaling utility factor with a vehicle's all electric range. For example, PHEVs certifying with all electric range greater than 50 miles could claim higher fleet utility factors than those with 20-mile electric range.

[3] https://www.sae.org/standards/content/j2841_201009/

[4] https://www.caranddriver.com/volkswagen/tiguan

Advanced technology credit multipliers for PHEV, BEV and FCEV HDPUVs should end before MY 2027.

Analyses by ICCT and researchers at Carnegie Mellon have shown that extended use of super credits in the light-duty sector has resulted in the unintended consequence of increased emissions from the non-ZEV fleet as it is allowed to emit more under a fleet average regulatory structure that includes averaging, banking and trading provisions.[5,6] Given the considerable incentives created by the IRA, IIJA, and other federal and state programs supporting the production, sale, and operation of medium-duty zero tailpipe vehicles, MECA agrees that Advanced Technology Multipliers for PHEVs, BEVs and FCEVs are no longer needed for medium-duty vehicles beyond MY 2026. Similar to the light-duty sector, an over-incentivized credit scheme for medium-duty ZEVs is likely to result in market distortions that will reduce the broader deployment of electric and hydrogen fuel cell powertrains and thus decrease the benefits anticipated by the standards.

MECA supports NHTSA retaining off-cycle FCIV for the CAFE Program (light-duty vehicles) and off-cycle credits for heavy-duty pickups and vans since these provide real-world emission benefits.

We continue to support NHTSA's off-cycle credit program for recognizing the breadth of engineering ingenuity to reduce real-world fuel consumption through a verifiable credit process. This program has offered a method for vehicle manufacturers to apply for off-cycle fuel consumption improvement values (FCIV) through three pathways with increasing levels of complexity. We agree that the five-cycle approval process is complex and thus has had limited subscribership. The program requires that off-cycle technologies be fully integrated into vehicles, and thus suppliers have had a difficult time generating enough evidence to convince their customers to commit resources to demonstrate the technology across a fleet of vehicles without any indication of the amount of credits the technology may deliver. Furthermore, suppliers have found it difficult to take advantage of the 5-cycle pathway to generating data toward demonstrating the fuel reduction benefits of a technology to their customers without access to the methodology the agency uses for calculating the final credit value.

Given the phase out of credits in both light and heavy-duty regulations (e.g., advanced technology multiplier credits for medium- and heavy-duty vehicles are phasing out by 2027), we believe this could lead to increased interest and use of the current off-

[5] A. Jenn, I. L. Azevedo and J. J. Michalek, "Alternative-fuel-vehicle policy interactions increase U.S. greenhouse gas emissions," Transportation Research Part A: Policy and Practice, vol. 124, pp. 396-407, 2019.

[6] R. Minjares and J. Hannon, "Adapting US heavy-duty vehicle emission standards to support a zero-emission commercial truck and bus fleet," 2022.

cycle credit program for both CAFE and HD fuel efficiency programs. We support continuation of off-cycle menu credits.

MECA supports inclusion of the role of battery critical materials in NHTSA's rulemaking analysis.

MECA supports NHTSA's technology neutral, performance-based approach to reduce fuel consumption from light-duty vehicles and heavy-duty pickups and vans through improvements in the efficiency of today's vehicles combined with accelerated introduction of electric vehicles. We agree with the Agency's conclusion that projected penetration of electric vehicles will provide significant benefits from the light-duty fleet. However, based on current rates of electric vehicle sales growth, charging infrastructure development and critical minerals supply chain development, there is still considerable uncertainty in the projected pace of future electric vehicle penetration.

Table 2 displays fueleconomy.gov data with stated battery capacities for selected vehicles. It should be noted that the amount of battery material needed to manufacture each full battery electric vehicle could be deployed to manufacture five PHEVs or 62 HEVs. One can calculate the amount of fuel consumption and CO_2 reduced each year as a function of battery capacity (kWh) and miles driven. On a vehicle basis, the fuel economy of the battery electric vehicle (Tesla Model Y Long Range AWD) is 122 mpge compared to 94 mpge (electric and gas operation) for the plug-in hybrid (Toyota RAV4 Prime) assuming that only 69.3% of its operation is all-electric. However, on an equivalent battery capacity basis, the last row of Table 3 shows that HEVs and PHEVs use the available battery materials more efficiently than BEVs by providing greater fuel economy benefits per kWh of battery capacity. This improved efficiency of hybrids is due to the higher rate of cycling of their smaller hybrid battery capacities. As a result, a far greater cumulative fuel economy benefit can be realized by deploying the 5 PHEVs at 94 mpge than by the operation of the one BEV at 122 mpge.

To fully electrify a medium-duty vehicle, a minimum of a 75 to 100kWh battery would be needed. The same analysis could be run as for light-duty vehicles above to compare example medium-duty vehicles with varying degrees of electrification. The result would be similar with the conclusion that fuel economy improvements per kWh of battery are maximized for hybrid powertrains.

These analyses illustrate that strategically deploying HEV and PHEV powertrains as well as BEVs can yield significantly greater fuel economy benefits on a battery capacity and critical minerals utilization basis thus reducing battery critical mineral supply chain pressures and providing manufacturers greater flexibility in achieving CAFE and fuel efficiency goals. In summary, we highlight that greater early market penetration of hybrids and PHEVs will moderate near term critical minerals usage, yielding greater mpge/kWh but also per unit of critical minerals (e.g., Li, Ni, Co, Mn). This will be an essential benefit while domestic sources of these materials are developed.

Table 2. Comparison of Battery Capacities of Conventional, Full Hybrid, Plug-in Hybrid and Battery Electric Vehicles

	2023 Toyota RAV4 AWD 2.5L, 4cyl. 	2023 Toyota RAV4 AWD Hybrid 2.5L, 4cyl. 	2022 Toyota RAV4 Prime AWD PHEV 2.5L, 4cyl. 	2023 Tesla Model Y Long Range AWD BEV 
Fuel Economy (mpge)	28	40	Elec + Gas: 94 Gas only: 38	Electric 122
Tailpipe + Upstream GHG (grams/mile)	383	268	190 *assumes 69.3% electric only operation	110 **based on U.S. average grid intensity
Fuel Economy Benefit (mpge)	-na-	12	66	94
Vehicle Battery Capacity (kWh)	-na-	1.6	18.1	100
Vehicles Produced from 100 kWh Battery Capacity	-na-	62	5.5	1
Fuel Economy Benefit per kWh Battery Capacity (mpge)	-na-	7.5	3.7	0.94

NHTSA should work with other agencies, like the Joint Office on Energy and Transportation, in prioritizing the deployment of DC fast chargers and setting minimum charger efficiency standards to ensure that infrastructure funds are spent on chargers with the best utilization of electric power.

The prioritization of building forward-looking vehicle charging infrastructure is critical to the penetration of electric vehicles. Furthermore, analogous to vehicle electronic design and material selection impacts to electric vehicle efficiency, similar approaches can be used to improve charger efficiency in delivering the maximum power to the vehicle.

While overnight charging at lower power may be appropriate for most light-duty vehicle use and certain medium-duty vehicle applications, we recommend the NHTSA coordinate with other offices in DOT as well as with EPA and DOE to prioritize the planning and building of direct current fast chargers (DCFC). The planning of public DCFCs is indispensable to allow in-service electric vehicles to address unforeseen day-to-day vehicle use variables (i.e., weather, traffic conditions, needed route changes, etc.). The availability of strategically placed, publicly accessible DCFCs prevents vehicles becoming inoperable due to these use variables, allowing vehicles to be rapidly charged and quickly placed back into service while minimizing interruptions to vehicle operations, traffic disruptions from vehicle strandings and maximizing the utilization of available space for heavy-duty vehicle recharging.

DCFC is also crucial to address long-term medium-duty vehicle charging needs. Many commercial EVs will need to achieve fast charging times to encourage fleet owners to transition to e-mobility. This is particularly true for those vehicle operators who do not have access to charging at their own facilities. EV fleet adopters with slower rate overnight charging should also diversify their charging assets with DCFCs to have more flexibility as their fleets grow and unforeseen needs arise to charge vehicles and return them to service.

Additionally, DCFCs futureproof infrastructure investments by allowing fleet operators to immediately convert and deploy BEVs while also allowing them to remain up to date with advancements in battery technology. Vehicle batteries are quickly improving in size, chemistry, energy density, and efficiency resulting in increased vehicle range. This range improvement will, however, require faster charging capabilities. While medium-duty BEV vehicles typically require larger batteries with increasing power density than light-duty vehicles, DCFCs enable quicker and more efficient charging of these vehicles. In addition, site and infrastructure owners maximize their investment because DCFCs enable site-readiness for future DCFC expansions while allowing the best utilization of available space and higher turnover of serviced vehicles.

DCFCs also allow for bidirectional charging which futureproofs infrastructure investment further by providing support for increasing electricity demand. Vehicle-to-Grid ("V2G") technology can help address energy use and manage peak demand times and costs, as well as serve as backup power during an outage. As EV adoption increases, this technology becomes more critical to enable sustainable grid management, grid resilience, utilization, and national security protection.

MECA also recommends the NHTSA work with others in a whole of government approach to consider national certification, such as UL Certification, for EV supply equipment to provide consistency, quality, safety, efficiency and compliance. A Certificate of Compliance will mean the product has passed a series of rigorous tests to demonstrate performance, safety, quality, and serviceability, while enhancing sustainability, strengthening security, and managing risk. National certification also supports local permitting efficiency, therefore, helps fast track deployment of charging stations.

For these reasons, MECA urges NHTSA to work with other government agencies, such as the Joint Office for Transportation and Energy, and industry to develop national standards for minimum charger efficiency which will ensure the efficient energy utilization and lowest operating cost for electric vehicles. With regards to technology, several suppliers of vehicle power electronics are applying similar electric efficiency technology innovation to the development of more efficient chargers to minimize switching losses and deliver maximum power to the battery. This is important to consumers and fleets as charging losses reduce the total energy to the battery and increase operating cost. Furthermore, it is important to the environment because these losses represent electricity that is generated but never used. The difference in electric efficiency between the first generation of chargers, that are deployed in the field today, and the advanced, second-generation chargers can be as much as 10-20%. This becomes significant as electric vehicle penetration increases into the future.

MECA appreciates NHTSA's technology neutral approach to fuel economy regulation. We have summarized several technologies that improve the efficiency of vehicles.

Cylinder Deactivation and Variable Valve Actuation

Cylinder deactivation (CDA) is an established technology on light-duty gasoline vehicles, with the primary objective of reducing fuel consumption and CO_2 emissions. This technology combines hardware and software computing power to, in effect, "shut down" some of an engine's cylinders, based on the power demand, and keep the effective cylinder load in an efficient portion of the engine map without burning more fuel. Based on decades of experience with CDA on gasoline passenger cars and trucks, CDA is now being adapted for diesel engines. On a diesel engine, CDA is programmed to operate differently than on gasoline engines, with the goal of the diesel engine running hotter in low-load situations by having the pistons that are firing do more work. This programming is particularly important for vehicles that spend a lot of time in creep and idle operation modes. During low-load operation, CDA has resulted in exhaust temperatures increasing by 50°C to 100°C when it is most needed to maintain effective conversion of NOx in the selective catalytic reduction (SCR) catalyst bed. In some demonstrations, CDA has been combined with a 48-V mild hybrid motor with launch and sailing capability to extend the range of CDA operation over the engine, and this may deliver multiplicative fuel savings from these synergistic technologies[7].

Modern Turbochargers

Modern turbochargers have a variety of available design options enabling lower CO_2 emissions by improving thermal management capability, such as: i) state of the art aerodynamics, ii) electrically-actuated wastegates that allow exhaust gases to by-pass the turbocharger to increase the temperature in the aftertreatment, and iii) advanced ball bearings to improve transient boost response. These and other technologies are available to support fuel economy improvements. More advanced turbochargers are designed with a variable nozzle that adjusts with exhaust flow to provide more control of intake pressure and optimization of the air-to-fuel ratio for improved performance (e.g., improved torque at lower speeds) and fuel economy. These variable geometry turbochargers (VGT), also known as variable nozzle turbines (VNT) and variable turbine geometry (VTG), also enable fuel efficiency through improved thermal management capability to enhance aftertreatment light-off. Finally, modern turbochargers have enabled engine and vehicle manufacturers the ability to downsize engines, resulting in fuel savings without sacrificing power and/or performance. The latest high-efficiency turbochargers are one of the more

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[7] https://www.meca.org/wp-content/uploads/resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf

effective tools demonstrated in the DOE SuperTruck program[8]. In addition to affecting the power density of the engine, turbochargers play a significant role in NOx and CO_2 regulations compliance. Continuous improvement in turbocharger technology is making it possible to run very lean combustion (high air/fuel ratios), which increases efficiency. This improvement allows for very low particulate generation and even lower engine-out NOx.

Turbo-compounding

Turbo-compounding is a variant of turbocharger technology that allows for the energy from the exhaust gas to be extracted, converted to mechanical or electrical energy and either mechanically added to the engine crankshaft through a transmission or stored electrically for opportunistic use in other driving conditions. Mechanical turbo-compounding has been employed on some commercial diesel engines, and NHTSA along with EPA estimated penetration to reach 10% in the U.S. by the time the Phase 2 GHG Regulation is fully implemented in 2027[9]. While turbo-compounding has the potential to reduce fuel consumption, it can result in lower exhaust temperatures that can challenge aftertreatment performance. Therefore, it is important to consider turbo-compound designs that incorporate bypass systems during cold start and low load operation or electrically driven turbo-compounding systems where the unit can be placed after the aftertreatment system.

Driven Turbochargers

Driven turbochargers can be used to control the speed of the turbomachinery independently of the engine's exhaust flow and vary the relative ratio between engine speed and turbo speed. Driven turbochargers may be utilized for several reasons, including performance, efficiency, and emissions. Considered an 'on-demand' air device, a driven turbocharger also receives transient power from its turbine. During transient operation, a driven turbocharger will behave like a supercharger and consume mechanical or electrical energy to accelerate the turbomachinery for improved engine response. At high-speed operation, the driven turbocharger will return mechanical or electrical power to the engine in the form of turbo-compounding, which recovers excess exhaust power to improve efficiency. This cumulative effect lets a driven turbocharger perform all the functions of a supercharger, turbocharger, and turbo-compounder.

Mild Hybridization

48-volt systems can be found on many light-duty vehicle models (primarily in Europe) from Mercedes, Audi, VW, Renault and PSA. In the U.S., Stellantis is offering a 48-volt system on the RAM 1500 pick-up and the Jeep Wrangler under the eTorque trademark.

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[8] Navistar, "Final Scientific/Technical Report for SuperTruck Project: Development and Demonstration of a Fuel-Efficient, Class 8 Tractor & Trailer Engine System," 2016.

[9] U.S. EPA, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles -- Phase 2," Federal Register, pp. 73478-74274, 25 October 2016.

48-volt mild hybrid electrical systems and components are expected to make their way onto commercial diesel vehicles in the near future. Because the safe voltage threshold is 60 volts, which is especially important when technicians perform maintenance on the electrical system, 48-volt systems are advantageous from an implementation standpoint. From a cost perspective, 48-volt systems include smaller starter and wire gauge requirements, offering cost savings from a high voltage architecture of a full hybrid. The U.S. Department of Energy's SuperTruck II program teams employed 48-volt technologies on their vehicles to demonstrate trucks with greater than 55% brake thermal efficiency. A recent study demonstrated through model-based simulations that a 48-volt technology package combined with advanced aftertreatment can achieve a composite FTP emission level of 0.015 g/bhp-hr[10].

Similar to the passenger car fleet, truck OEMs are considering replacing traditionally mechanically-driven components with electric versions to gain efficiency. Running accessories off 48-volt electricity rather than 12-volts is more efficient due to reduced electrical losses and because components that draw more power, such as pumps and fans, have increased efficiency when operating at higher voltages. The types of components that may be electrified include, electric turbos, electronic EGR pumps, AC compressors, electrically heated catalysts, electric cooling fans, oil pumps and coolant pumps, among others. Another technology that 48-volt systems could enable is electric power take-offs rather than using an engine powered auxiliary power unit or idling the main engine during hoteling while the driver rests. MECA members supplying commercial 48-V components for commercial vehicles believe that the technology may be feasible to apply to a limited number of engine families by 2024, and it is likely to see greater penetration by 2027, especially on Class 8 line-haul where full hybridization is less practical.

Mild hybridization covers a range of configurations, but a promising one includes an electric motor/generator, regenerative braking, electric boost and advanced batteries. Stop/start deployment also provides a thermal management benefit to the aftertreatment by preventing cooling airflow through the aftertreatment during hot idle conditions. In this way, 48-volt mild hybridization is complementary technology to CDA and start-stop capability, allowing the combination of multiple technologies on a vehicle to yield synergistic benefits and justify the cost. By shutting off the engine at idle or motoring using start/stop, micro hybrid technology can help to maintain aftertreatment temperature by avoiding the pumping of cold air through the exhaust. Capturing braking energy and storing it in a small battery for running auxiliary components when the engine is off offers another fuel saving strategy for OEMs to deploy.

In lighter medium-duty applications, advanced start-stop systems have been developed that use an induction motor in a 48-volt belt-driven starter-generator (BSG). When the engine is running, the motor, acting as a generator, will charge a separate battery. When the engine needs to be started, the motor then applies its torque via the accessory belt and cranks the engine instead of using the starter motor. The separate

[10] F. Dhanraj, M. Dahodwala, S. Joshi, E. Koehler, M. Franke and D. Tomazic, 2022-01-0555.

battery can also be recharged via a regenerative braking system. In addition to the start-stop function, a BSG system can enhance fuel economy even during highway driving by cutting off the fuel supply when cruising or decelerating. Such systems can also be designed to deliver a short power boost to the drivetrain. This boost is typically 10 to 20 kW and is limited by the capacity of the 48-V battery and accessory belt linking the motor to the crankshaft. New designs are linking the BSG directly to the crankshaft and allowing additional power boost of up to 30 kW to be delivered, giving greater benefits to light and medium commercial vehicles.[11]

Full hybridization and plug-in hybrids

Full hybrid configurations are currently found on several models of light-duty passenger cars and light trucks in the U.S. and a limited number of medium-duty trucks. These include PHEV models that can also be plugged-in to enable all-electric operation over a defined all-electric range (AER). A full hybrid can enable electrification of many of the components described above for mild hybrid vehicles, but the higher voltages allow for more parts to be electrified and to a larger degree of efficiency. Full hybrids implementing larger electric motors and batteries, can also support greater acceleration capability and regenerative braking power. Full hybrid vehicles have made the highest penetration into parcel delivery, beverage delivery and food distribution vehicles because they can take advantage of regenerative braking in urban driving[12]. We expect to see some application of full hybrids combined with low NOx engines to reduce fuel consumption in several vocational and local delivery applications. Integrated electric drivetrain systems, consisting of a fully qualified transmission, motor and power electronics controller, are now commercially available. With power levels of over 160 kW and the ability to meet high torque requirements, these systems enable electrification of medium-duty commercial vehicles. There is also an increasing number of electric drivetrain solutions up to 300 kW that are suitable for medium and heavy-duty vehicles that can be used with either battery or fuel cell power sources[30].

Plug-in hybrids (PHEVs) can be practical for light and medium- duty trucks (e.g., Class1 through 3) that do not travel long distances or operate for long periods of time without returning to a central location. In addition, serial plug-in hybrids which employ an engine operating only as a generator to charge the traction battery to extend range, offer operational flexibility for commercial vehicles while full electric vehicles and their needed infrastructure are established. It is worth noting that both HEVs and PHEVs are able to achieve significant fuel economy benefits compared to their conventional vehicle counterparts by employing relatively low-capacity batteries. Further discussion on efficient use of battery critical materials is presented below and displayed in Table 2.

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[11] https://www.meca.org/wp-content/uploads/resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf
[12] CARB, "Draft Technology Assessment: Heavy-Duty Hybrid Vehicles," 2015.

Conclusion

In conclusion, MECA appreciates NHTSA staff's hard work and dedication in developing the proposed CAFE passenger car and light truck standards as well as fuel efficiency standards for heavy-duty pickup trucks and vans. We support the proposal with modifications based on our comments. The proposal coupled with our suggested modifications would result in cost effective fuel economy improvement to vehicles that would benefit millions of Americans. MECA believes that the standards are technically achievable while there remains uncertainty concerning the BEV penetration timelines proposed for implementation. Our industry is prepared to do its part and deliver cost-effective and durable advanced emission control and efficiency technologies to the light- and medium-duty sector to assist in improving the energy efficiency of all vehicles regardless of propulsion system.

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