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15 October 2023
U.S. National Highway Traffic Safety Administration
Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE
Washington, DC 20590

Docket ID No. NHTSA-2023-0022

RE: International Council on Clean Transportation (ICCT) comments on NHTSA proposed rule, titled, "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"

Dear Joseph Bayer:

The International Council on Clean Transportation (ICCT) welcomes the opportunity to provide comments on the NHTSA'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. 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 commend NHTSA on its continuing efforts to improve fuel economy of passenger cars and light trucks and heavy-duty pickup trucks and vans. NHTSA's standards have paved the way for more efficient vehicles and delivered enormous gasoline consumption reduction, energy security, economic, and climate and health benefits for the United States. This proposed rulemaking is one more step in NHTSA's progress in reducing fuel consumption and improving energy security, economic benefits, and climate and air pollution from transportation.

These comments provide technical observations on NHTSA's proposal that the agency may consider in finalizing its rulemaking. We would be glad to clarify or elaborate on any points made in these comments. NHTSA staff can feel free to contact our U.S. Passenger Vehicle Program Lead, Pete Slowik (peter.slowik@theicct.org) with any questions.

Sincerely,

Rachel Muncrief, PhD
Acting Executive Director
International Council on Clean Transportation

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# SUMMARY OF ICCT COMMENTS

ICCT supports NHTSA's proposed Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027-2032. The proposed standards are critical to achieving the pace and scale of needed fuel savings and transportation emission reductions in the United States, where there is a clear and urgent need to rapidly transition to cleaner vehicles. Continued and strengthened standards are necessary to reduce petroleum consumption, bolster consumer savings, and protect public health and deliver on national environmental obligations. We support the proposed standards that would dramatically reduce fuel consumption and climate and air pollution from new passenger vehicles and deliver billions of dollars in net benefits.

We believe the proposed fuel efficiency improvements are feasible because today's technology, policy, and market landscape have primed the market for a rapid transition to cleaner vehicles. Our research shows that there are numerous combustion and electric vehicle technologies available today that enable automakers to cost-effectively meet NHTSA's proposed fuel economy standards, and we believe that NHTSA's estimates of battery-electric and plug-in hybrid electric vehicle penetration rates under the No Action and four "action" alternatives are reasonable and feasible.

Substantial public and private sector investments and a comprehensive package of federal and state level policies make the timing and stringency of the proposed rule achievable, feasible, and cost-effective. At the federal level, the combination of substantial consumer and industry incentives from the $370 billion allocated to climate and clean energy investments through the Inflation Reduction Act of 2022 (IRA) will accelerate the shift to electric vehicles while supporting a domestic supply chain and charging infrastructure buildout. In parallel, the Bipartisan Infrastructure Law complements the IRA by investing $7.5 billion in electric vehicle charging infrastructure, $10 billion in clean transportation, and more than $7 billion in battery components, critical minerals, and materials.

Globally, automakers have already announced over $1.2 trillion in investments in electrification. These investments will lead to greatly expanded model line-ups and production volumes, technological advancements, and reduced costs. Battery mineral resources and production capacity are sufficient to meet the standards. There are enough mineral resources available to support a global transition to EVs and there are substantial ongoing investments in new projects along the mineral supply chain in the U.S. and in friendly countries. Significant and growing battery recycling capacity, along with battery technology diversification and improving EV efficiency, will reduce pressure on EV mineral demand. Domestic battery production capacity is quickly ramping up, already increasing by more than one-third since the IRA was passed. With major announced public, private, and utility investment in chargers, the infrastructure is also being built to meet the growth in electric vehicle penetration rates in NHTSA's No Action scenario and the four alternative scenarios. The electric vehicle penetration rates assumed are also feasible when considering announcements from auto manufactures; Ford, General Motors, Mercedes-Benz, Audi, and others have committed to selling 100% zero-emission vehicles globally or in leading markets by 2035.

The United States is not alone in its commitment to transition to cars and trucks with much greater fuel economy. Many other jurisdictions including the European Union, the United Kingdom, Chile, New Zealand, Canada, South Korea, Japan, and several others have made great progress on improving fuel economy and have proposed or already enacted strong targets for greatly continued improvements that go well beyond NHTSA's proposal.

Another reason NHTSA's proposal is feasible is that there is potential for additional cost-effective fuel economy improvements beyond what NHTSA has modeled. Many existing and recently announced ICEV technology improvements have ample room for increased application throughout the ICEV fleet. ICCT has identified several technologies that are commercially available and could significantly and cost-effectively improve ICE vehicle efficiency at a cost lower than that estimated by NHTSA. For these reasons we believe that the standards can be met at lower cost than analyzed.

ICCT supports NHTSA's proposed improvements on a number of technical design elements that will strengthen the overall rule. ICCT strongly supports NHTSA's proposals to update its air-conditioning (AC) and off-cycle (OC) credit programs. Specifically, ICCT supports NHTSA limiting OC and AC credits to ICEVs, as the credits are based on ICE fuel consumption reductions. ICCT also supports the proposal to scale PHEV OC and AC credits by the utility factor. Finally, ICCT supports the proposal to phaseout OC credits by MY2031, and to eliminate the off-menu OC credit option starting with MY2027. On PHEVs, ICCT supports NHTSA using the proposed PHEV utility factor (UF) curve developed by EPA. This newly proposed UF curve is based on real-world PHEV usage data aligned with ICCT research.

ICCT supports the proposed Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027-2032 and recommends its finalization as quickly as possible. Doing so will provide a clear long-term signal that automakers, suppliers, and other stakeholders need to make needed investments with confidence.

Our detailed comments below provide further background, analysis, and references on these points.

# MARKET READINESS

The United States is primed to rapidly transition to substantially more efficient cars and trucks. The global transition to zero-emission vehicles is accelerating, and the U.S. is the third largest electric vehicle market, behind China and Europe. In 2022, new U.S. plug-in electric vehicle sales reached nearly 1 million units, representing over 7% of new light-duty vehicle sales.[1] This growth is expected to continue, as evidenced by the more than $1.2 trillion in announced automaker spending on electric vehicles, widespread consumer demand, and billions of dollars in new federal tax credits, incentives, and investments.[2] Many electric vehicles have multi-month long wait times, indicating that demand is outpacing supply, and consumer research surveys show that demand for BEVs in the United States continues to increase and that 30% of licensed drivers aren't even considering gasoline vehicles for their next purchase or lease.[3] Substantial public and private sector investments and state and federal policies have primed the market for a rapid shift to electric vehicles.

The Inflation Reduction Act (IRA) of 2022 will accelerate electric vehicle sales in the United States across all vehicle types. The $370 billion allocated to climate and clean energy investments dramatically expands tax credits and incentives to deploy more clean vehicles, including commercial vehicles, while supporting a domestic EV supply chain and charging infrastructure buildout. IRA transportation sector provisions will accelerate the shift to zero-emission vehicles by combining consumer and manufacturing policies. Consumer tax credits for new and used EVs and tax credits for commercial EVs, along with individual and commercial charging infrastructure tax credits, will increase sales. Domestic supply chain incentives and investments will boost EV manufacturing and battery production. Critical mineral mining and refining incentives will bolster industrial development.

An ICCT and Energy Innovation study assesses the future impact of the IRA on electrification rates for LDV sales in the United States through 2035.[4] We analyze the value of the personal and commercial EV tax credits, factoring in the various supply chain, income, and price caps on new EVs, and combine this with new estimates of future light-duty EV cost declines. We find that, on average over the period 2023–2032, the IRA tax credits will reduce EV purchase costs by $3,400 to $9,050 and accelerate the timing for price parity with combustion vehicles. Using methodologies from the Energy Policy Simulator, we project how these changing costs and incentives over time will affect the LDV markets in the United States.

Figure 1 summarizes the results from the ICCT and Energy Innovation IRA study. It shows the findings of estimated new electric vehicle sales shares for different IRA scenarios depending on how certain provisions are implemented and how the value of incentives is passed on to consumers. The figure shows our modeled projection of how the IRA will accelerate

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1 Based on data from EV-Volumes. (2023). https://www.ev-volumes.com/datacenter/

2 Lienert, P. (2022, October 25). Exclusive: Automakers to double spending on EVs, batteries to $1.2 trillion by 2030. *Reuters*. https://www.reuters.com/technology/exclusive-automakers-double-spending-evs-batteries-12-trillion-by-2030-2022-10-21/

3 Kiai, E. (2023, May 6). Waiting times for new electric car deliveries down by 42% since October peak. *Electrifying*. https://www.electrifying.com/blog/article/waiting-times-for-new-electric-car-deliveries-down-by-42-since-october-peak; Consumer Reports (2023). Automakers must increase production of electric vehicles or risk losing customers, new analysis finds. https://advocacy.consumerreports.org/press_release/new-analysis-of-consumer-ev-demand/

4 Slowik, P., Searle, S., Basma, H., Miller, J. Zhou, Y., Rodriguez, F., Buysse, C., Kelly, S., Minjares, R., Pierce, L. (ICCT) Orvis, R., and Baldwin, S. (Energy Innovation). (2023). Analyzing the impact of the inflation reduction act on electric vehicle uptake in the United States. https://theicct.org/publication/ira-impact-evs-us-jan23/

electrification. By providing thousands of dollars in financial incentives, the IRA unlocks widespread consumer benefits. We find rapid projected EV uptake when considering both expected manufacturing cost reductions and the IRA incentives, as well as state policies. By 2030, we find a range of a 48%–61% projected EV sales share, increasing to 56%–67% by 2032, the final year of the IRA tax credits.

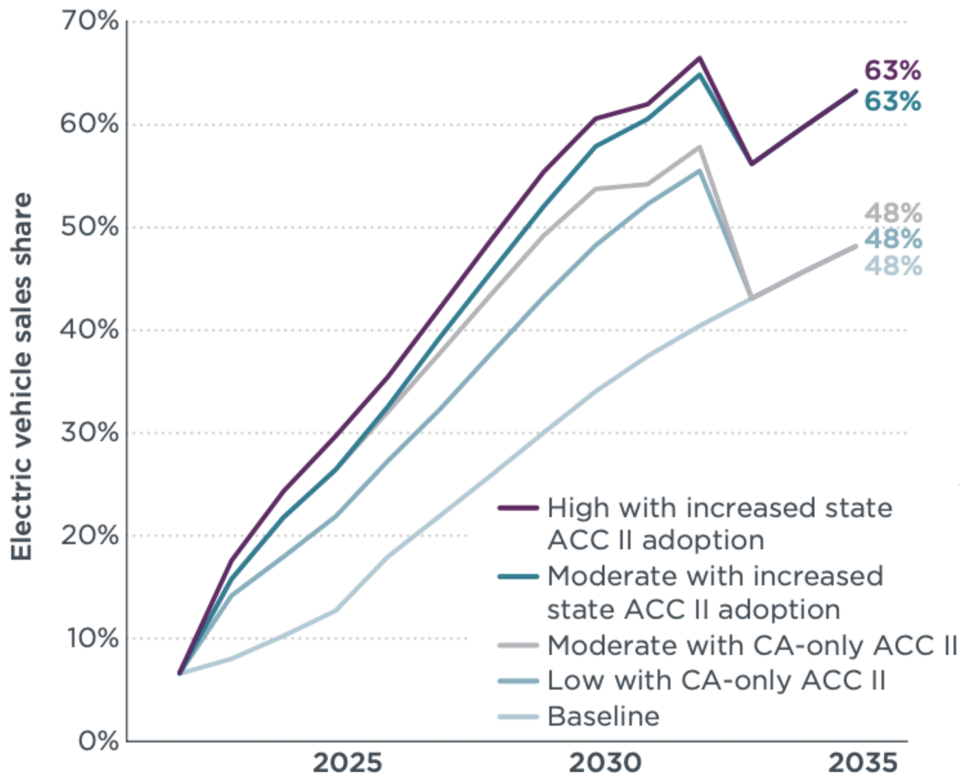


**Figure 1.** Baseline, Low, Moderate, and High projections of EV sales share for light-duty vehicles, considering ACC II adoption in only California versus increased states[5]

In parallel, states are also adopting their own zero-emission vehicle regulations, investments, consumer incentives, planning, and infrastructure deployment. California's Advanced Clean Cars II (ACC II) regulations will require dramatic reductions in light-duty vehicle emissions to 100% zero-emissions by 2035 through the Zero-Emission Vehicle Regulation and the Low-emission Vehicle Regulations.[6] Many other U.S. states follow California's leadership on automotive emissions regulations. As of September 2023, California, Massachusetts, New York, Oregon, Vermont, Virginia, and Washington have adopted ACC II. It is likely that many other states will continue to follow California's leadership and adopt the new ACC II Program to benefit from the anticipated emissions reduction and health benefits of the program.[7] Many additional states currently follow the Advanced Clean Cars regulations through model year

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[5] ICCT and Energy Innovation. (2023). Analyzing the impact of the inflation reduction act on electric vehicle uptake in the United States. https://theicct.org/publication/ira-impact-evs-us-jan23/

[6] California Air Resources Board. (2023). Advanced Clean Cars II Regulations: All new passenger vehicles sold in California to be zero emissions by 2035. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii

[7] Houk, J., Huang, J., and Sussman. (2023). Benefits of adopting California's Advanced Clean Cars II standards in sixteen U.S. states. Sonoma Technology Inc. Retrieved from https://theicct.org/publication/benefits-of-state-level-adoption-of-california-acc-ii-regulations/

2026; as of 2022, 17 U.S. states have adopted all or part of California's low-emission and zero-emission vehicle regulations, and about 37% of national new light-duty vehicle sales meet California's emission standards.[8]

The U.S. share of global automaker electric vehicle investments is increasing, largely driven by these state and federal policies and investments. Research from January 2023 estimates that $210 billion in automaker electric vehicle manufacturing and $54 billion in battery production investments had been announced for the U.S.[9] These electric vehicle and battery manufacturing investments will lead to greatly expanded model line-ups and production volumes, technological advancements, and reduced costs.

New government and private sector investments and sustained commitments will help build out the charging infrastructure needed to support accelerated electrification.[10] Norway – the world's electric vehicle sales share leader – achieved nearly 80% EV sales in 2022 with one public charger for every 26 EVs.[11] Significant resources are already being dedicated to charging in the United States, including the $7.5 billion allocation from the IIJA as well as several billions of dollars in power utility and private sector investment.[12] For example, British Petroleum announced plans to invest $1 billion in EV charging in the U.S. by 2030.[13] Automakers are investing too – GM, working with its dealers, aims to install up to 40,000 public charging stations across the U.S. and Canada.[14] Globally, Bloomberg New Energy Finance expects $100 billion to be spent to grow charging infrastructure in the next 3 years alone.[15] In parallel, state infrastructure planning is underway, with all 50 states, DC, and Puerto Rico submitting and receiving approval for their National Electric Vehicle Charging Network plans in 2022.[16]

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[8] California Air Resources Board. (May 13, 2022). States that have adopted California's vehicle standards under Section 177 of the Federal Clean Air Act. https://ww2.arb.ca.gov/sites/default/files/2022-05/%C2%A7177_states_05132022_NADA_sales_r2_ac.pdf

[9] Gabriel, N. (2023, January 12). $210 billion of announced investments in electric vehicle manufacturing headed for the U.S. *Atlas EV Hub.* https://www.atlasevhub.com/data_story/210-billion-of-announced-investments-in-electric-vehicle-manufacturing-headed-for-the-u-s/

[10] Searle, S., Kodjak, D., and Slowik, P. (2023, April 26). Infrastructure and supply chains won't hold up EPA's proposed light and medium-duty vehicle standards. *International Council on Clean Transportation.* https://theicct.org/infrastructure-and-supepas-proposed-ldv-mdv-standards-apr23/

[11] Johnson, P. (2023, January 2). This is the Norway – nation hits record EV share in 2022 on its way to ending gas car sales. *Electrek*. https://electrek.co/2023/01/02/norway-hits-record-ev-share-in-2022/; Kok, I., and Hall, D. (2023). Battery electric and plug-in hybrid electric vehicle uptake in European cities. *International Council on Clean Transportation*. https://theicct.org/publication/bev-phev-european-cities-mar23/

[12] The White House. (2023a). Fact sheet: Biden-Harris administration announces new standards and major progress for Made-in-America National network of Electric vehicle chargers. https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/; Electric utility filings. *Atlas EV Hub.* https://www.atlasevhub.com/materials/electric-utility-filings/

[13] British Petroleum (2023, February 15). BP plans to invest $1 billion in EV charging across US by 2030, helping to meet demand from Hertz's expanding EV rentals. https://www.bp.com/en_us/united-states/home/news/press-releases/bp-plans-to-invest-1-billion-in-ev-charging-across-us-by-2030-helping-to-meet-demand-from-hertzs-expanding-ev-rentals.html

[14] General Motors. (2022, December 7). GM advances dealer community charging program. https://news.gm.com/newsroom.detail.html/Pages/news/us/en/2022/dec/1207-charging.html

[15] Bloomberg NEF. (2023, January 20). Next $100 Billion EV-Charger spend to be super fast. https://about.bnef.com/blog/next-100-billion-ev-charger-spend-to-be-super-fast/

[16] U.S. Department of Transportation. (2022, September 27). President Biden's Bipartisan Infrastructure Law provides $5 billion to help States install EV chargers along interstate highways. https://highways.dot.gov/newsroom/historic-step-all-fifty-states-plus-dc-and-puerto-rico-greenlit-move-ev-charging-networks

In addition to all this industry investment in EV manufacturing, battery production, and the battery material supply chain, substantial investments are underway in the electric power sector. From 2012 through mid 2022, about $3.6 billion in utility transportation electrification investment plans have been approved across the country.[17] These investments include upgrades in grid capacity, safety, resilience, and managed charging. The U.S. already has enough power generation and transmission capacity to fuel the EV expansion over the next few years.[18] Meeting the 2050 demand requires about 1% per year growth in electricity production, well below the 3.2% average annual growth rate for the electricity generation over the past 70 years.[19]

There is evidence that it should be possible to quickly scale up investments into mining and battery production with careful planning and investment. There are more than enough minerals available for a global transition to EVs.[20] With the IRA's Advanced Manufacturing Production Tax Credit and the domestic content provisions in the Clean Vehicle Tax Credit, the U.S. directly incentivizes mining, recycling, and battery production on U.S. soil, and further supports establishing resilient material supply chains from friendly countries. The manufacturing subsidy of $45/kWh cuts about one third of total battery costs (global average of $151 in 2022), making battery production in the U.S. even cheaper than in China.[21] This support showed an immediate effect. In response to the IRA, we saw a significant uptick by more than one-third in announced plans for battery production facilities, catching up with Europe.[22] Longer-term forecasts now indicate U.S. battery production capacity at 1 TWh by 2030.[23] A mapping compilation of U.S. EV supply chain investment from December 2022 shows that there are several dozen investments in minerals, battery production, recycling, and other electric vehicle facilities across the country.[24] A separate study by the U.S. Department of Energy compiled U.S. battery supply chain announcements and found over $100 billion announced as of May 2023 with over 160 new or expanded minerals, materials processing, and manufacturing facilities, and over 70,000

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[17] Lepre, N. (2022, September). Electric utility filing annual update. *Atlas Public Policy.* https://atlaspolicy.com/wp-content/uploads/2022/09/Electric-Utility-Filing-Brief-July-2021-through-June-2022-v2-1.pdf

[18] Houston, S. (2022, September 12). Can the electric grid handle EV charging? *Union of Concerned Scientist.* https://blog.ucsusa.org/samantha-houston/can-the-electric-grid-handle-ev-charging/

[19] Harto, C. (2023, May 10). Blog: Can the grid handle EVs? Yes! *Consumer Reports.* https://advocacy.consumerreports.org/research/blog-can-the-grid-handle-evs-yes/; Miller, T., and Bischof, A. (2020, November 20). Electricity Demand's COVID comeback. *Morningstar investor.* https://www.morningstar.com/stocks/electricity-demands-covid-comeback

[20] Slowik, P., Lutsey, N., and Hsu, C-W. (2020). How technology, recycling, and policy can mitigate supply risks to the long-term transition to zero-emission vehicles. *International Council on Clean Transportation.* https://theicct.org/publication/how-technology-recycling-and-policy-can-mitigate-supply-risks-to-the-long-term-transition-to-zero-emission-vehicles/ and Oge, M. (2023, May 16). History shows EPA's proposed vehicle emissions rule can be done – it's worth trillions! *Forbes.* https://www.forbes.com/sites/margooge/2023/05/16/history-shows-epas-proposed-vehicle-emissions-rule-can-be-done---its-worth-trillions/?sh=ea3150cc6275

[21] Bloomberg New Energy Finance. (2022, December 6). Lithium-ion battery pack prices rise for the first time to an average of $151/kWh. https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

[22] Benchmark Minerals. (2022, November 23). IRA lifts US battery pipeline growth in second half of the year, outpacing Europe. https://source.benchmarkminerals.com/article/ira-lifts-us-battery-pipeline-growth-in-second-half-of-the-year-outpacing-europe

[23] Benchmark Minerals. (2023, April 14). US EPA emissions rules ratchet up pressure on the battery supply chain. https://source.benchmarkminerals.com/article/us-epa-emissions-rules-ratchet-up-pressure-on-the-battery-supply-chain

[24] EV supply chain and investment map. (2022, December 21). Zero Emission Transportation Association. https://www.zeta2030.org/education-fund/investments

new jobs.[25] Specific recent examples from June 2023 include a $9.2 billion federal loan to Ford to greatly expand U.S. electric vehicle and battery production, and Hyundai's announcement to increase its EV investments to $28 billion while reducing China operations.[26]

By the agency's own estimates, NHTSA's proposed standards will bring profound private, external, and social benefits, with especially large net benefits from reduced fuel costs and reduced climate damages. Furthermore, shift to cleaner cars and trucks in the U.S. can strengthen domestic manufacturing and supply chains, increase industrial competitiveness, and create good-paying jobs.[27]

There is clear and compelling evidence that the United States market is primed to rapidly transition to cleaner cars and trucks. For the reasons outlined above, we believe that NHTSA's estimates of battery-electric and plug-in hybrid electric vehicle penetration rates under the No Action and four "action" alternatives are reasonable and feasible.

## COMPARISON WITH AUTOMAKER COMMITMENTS

Nearly every automaker has publicly committed to transitioning model line-ups to new technologies with substantially less fuel consumption, providing further evidence that NHTSA's estimates of battery-electric and plug-in hybrid electric vehicle penetration rates under the No Action and four "action" alternatives are reasonable and feasible. ICCT recognizes the increasing number of commitments made by automakers and the speed at which the automotive industry is electrifying its fleet. ICCT previously collected information and analyzed announcements made by automakers on ZEV targets through the end of 2022. The analysis, from ICCT's 2022 Global Automaker Rating report,[28] shows that 19 out of 20 top global automakers have made specific commitments on their pace of electrification.[29] For example, General Motors and Ford Motors (the second and third largest automakers in the U.S by 2022 sales), as well as Mercedes-Benz have committed to cease internal combustion engine in leading markets by 2035 as COP26 ZEV declaration signatories.[30]

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[25] U.S. Department of Energy. (2023, May 23). Investments in American-Made Energy: Battery supply chain investments. https://www.energy.gov/investments-american-made-energy

[26] Rathi, A., Natter, A., and Naughton, K. (2023, June 22). Ford gets $9.2 billion to help US catch up with China's EV dominance. *Bloomberg.* https://www.bloomberg.com/graphics/2023-ford-ev-battery-plant-funding-biden-green-technology/ and Yim, H., and Yang, H. (2023, June 20). Hyundai raises EV investment to $28 billion, to reduce China operations. *Reuters.* https://www.reuters.com/business/autos-transportation/hyundai-motor-invest-8541-billion-by-2032-accelerate-ev-plans-2023-06-20/

[27] The White House (2023b). Fact sheet: Biden-Harris Administration announces new private and public sector investments for affordable electric vehicles. https://www.whitehouse.gov/briefing-room/statements-releases/2023/04/17/fact-sheet-biden-harris-administration-announces-new-private-and-public-sector-investments-for-affordable-electric-vehicles/; Naimoli, S., Kodjak, D., German, J., and Schultz, J. (2017, May 23). International competitiveness and the auto industry: what's the role of motor vehicle emission standards? *International Council on Clean Transportation. https://theicct.org/publication/international-competitiveness-and-the-auto-industry-whats-the-role-of-motor-vehicle-emission-standards/*

[28] Shen, C., Fadhil, I., Yang, Z., Searle, S. (2023). The global automaker rating 2022: who is leading the transition to electric vehicles? *International Council on Clean Transportation.* https://theicct.org/publication/the-global-automaker-rating-2022-may23/.

[29] The top 20 automakers are selected based on the total light-duty vehicle sales in 2022 across six major markets: China, United States, Europe, Japan, India, and South Korea. About 90% of their global LDV sales were delivered in these six major markets.

[30] Ford Motors. (2021). Ford statements on signing the ambitious route zero initiative at COP26. Ford: Cologne, Germany. November 2021. https://media.ford.com/content/fordmedia/feu/en/news/2021/11/10/ford-statements-on-signing-the-ambitious-routezero-initiative-at.html

**Table 1.** Announcements ZEV sales target by automakers[31]

| Automaker | Announcements outlined in the proposed rule | Additional announcements as of 2022 |
|---|---|---|
| GM | In January 2021, General Motors announced plans to shift its light-duty vehicles entirely to zero-emissions by 2035. | In November 2021, GM signed the COP26 ZEV declaration aiming for a 100% ZEV sales target for LDVs in leading markets by 2035 including the U.S.[32] |
| Volvo Cars | In March 2021, Volvo announced plans to make only electric cars by 2030. | No update |
| VW | In March 2021, Volkswagen announced that it expected 50% of its U.S. sales to be all-electric by 2030. | No update |
| Honda | In April 2021, Honda announced a full electrification plan to take effect by 2040, with 40% of North American sales expected to be ZEV by 2030, 80% by 2035 and 100% by 2040. | No update |
| Ford | In May 2021, Ford announced that they expect 40% of their global sales will be all-electric by 2030. | In November 2021, Ford signed the COP26 ZEV declaration aiming for a 100% ZEV sales target for LDVs in leading markets by 2035 including the U.S.[33] |
| Stellantis | In June 2021, Fiat announced a move to all electric vehicles by 2030, and in July 2021 its parent corporation Stellantis announced an intensified focus on electrification across all of its brands. | In March 2022, Stellantis announced a 50% ZEV target by 2030 for LDVs in the United States.[34] |
| Mercedes-Benz | In July 2021, Mercedes-Benz announced that all its new architectures would be electric-only from 2025, with plans to become ready to go all-electric by 2030 where possible. | In November 2021, Mercedes-Benz signed the COP26 ZEV declaration aiming for a 100% ZEV sales target for LDVs in leading markets by 2035 including the U.S.[35] |
| Toyota | In December 2021, Toyota announced plans to introduce 30 BEV models by 2030 worldwide. | In December 2021, Toyota is committed to selling 3.5 million BEVs globally by 2030. This is roughly 32% of its LDV sales.[36] |
| Hyundai-Kia | Hyundai and Kia announced a global ZEV target of 50% and 45% by 2030 respectively. | In March 2022, Hyundai[37] and Kia[38] are committed to 36% and 30% global ZEV sales by 2030. |

[31] Announcements are targets reported through the end of 2022 and cover ZEV sales target in the U.S., leading markets, and/or global sales.
[32] COP26 ZEV declaration. (2021, November). Automotive manufacturer signatories. (COP26: Glasgow). https://cop26transportdeclaration.org/en/signatories/automotive-manufacturers/.
[33] COP26 ZEV declaration. (2021, November). Automotive manufacturer signatories. (COP26: Glasgow). https://cop26transportdeclaration.org/en/signatories/automotive-manufacturers/.
[34] Stellantis. (2022, March 1). Long-term strategic plan: Dare forward 2030. Stellantis: Amsterdam. https://www.stellantis.com/content/dam/stellantis-corporate/investors/events/strategic-plan-2030/2022_03_01_Strategic_Plan.pdf
[35] COP26 ZEV declaration. (2021, November). Automotive manufacturer signatories. (COP26: Glasgow). https://cop26transportdeclaration.org/en/signatories/automotive-manufacturers/.
[36] We estimate the ZEV sales share of the total LDV in 2030 based on Toyota's absolute ZEV sales target number of 3.5 million BEVs by 2030 and project the global LDV sales in 2030 based on Toyota's 2011-2022 annual CAGR from its worldwide production. Retrieved from https://global.toyota/en/company/profile/production-sales-figures/202212.html
[37] Hyundai. (2022, March). 2022 CEO Investor Day. Hyundai: Seoul. https://www.hyundai.com/content/hyundai/ww/data/ir/calendar/2022/0000000352/files/2022-ceo-investor-day-eng-220620.pdf.
[38] Kia Media. (2022, March). Kia CEO Investor Day presents 2030 roadmap to become global sustainability mobility leader. Kia: Seoul. https://press.kia.com/eu/en/home/media-resouces/press-releases/2022/Kia-CEO-Investor-Day.html.

| | | |
|---|---|---|
| Mazda | Mazda announced a global ZEV target of 25% by 2030. | No update |
| Nissan | Nissan announced a ZEV target of 40% by 2030 in the United States. | No update |
| Jaguar | Jaguar announced a global ZEV target of 100% by 2025. | No update |
| Land Rover | Land Rover announced a global ZEV target of 60% by 2030. | |

# INTERNATIONAL POLICY COMPARISON

The United States is not alone in its commitment to transition to cleaner cars. The number of national and subnational governments around the world that are committed to cleaner vehicles continues to rise. The sections below summarize and compare NHTSA's CAFE proposal with the standards in other leading markets around the world in terms of greenhouse gas emissions requirements, projections for electric vehicle uptake, and criteria pollutant emissions standards.

## Fuel consumption standards

Based on NHTSA's proposed fuel economy values, Figure 2 and Figure 3 illustrate the U.S. trajectories of average CO2 emissions performance and CO2 emissions targets for new passenger cars and light trucks, respectively, over the years, in comparison with other global vehicle markets that have CO2 emissions targets at least as of 2022. For a consistent basis of comparison, CO2 emissions values for all markets have been converted to the same U.S. test cycles (referred to as the CAFE cycle), where needed, using the ICCT cycle conversion factors.[39] The CO2 emissions targets are shown for both enacted and proposed targets for each country, where applicable including for the U.S.

[39] Kühlwein, J. et al. (2014). Development of test cycle conversion factors among worldwide light-duty vehicle CO2 emission standards. *International Council on Clean Transportation.* https://theicct.org/publication/development-of-test-cycle-conversion-factors-among-worldwide-light-duty-vehicle-co2-emission-standards/; Yang, Z. (2014). Improving the conversions between the various passenger vehicle fuel economy/CO2 emission standards around the world. *International Council on Clean Transportation.* https://theicct.org/improving-the-conversions-between-the-various-passenger-vehicle-fuel-economy-co2-emission-standards-around-the-world/

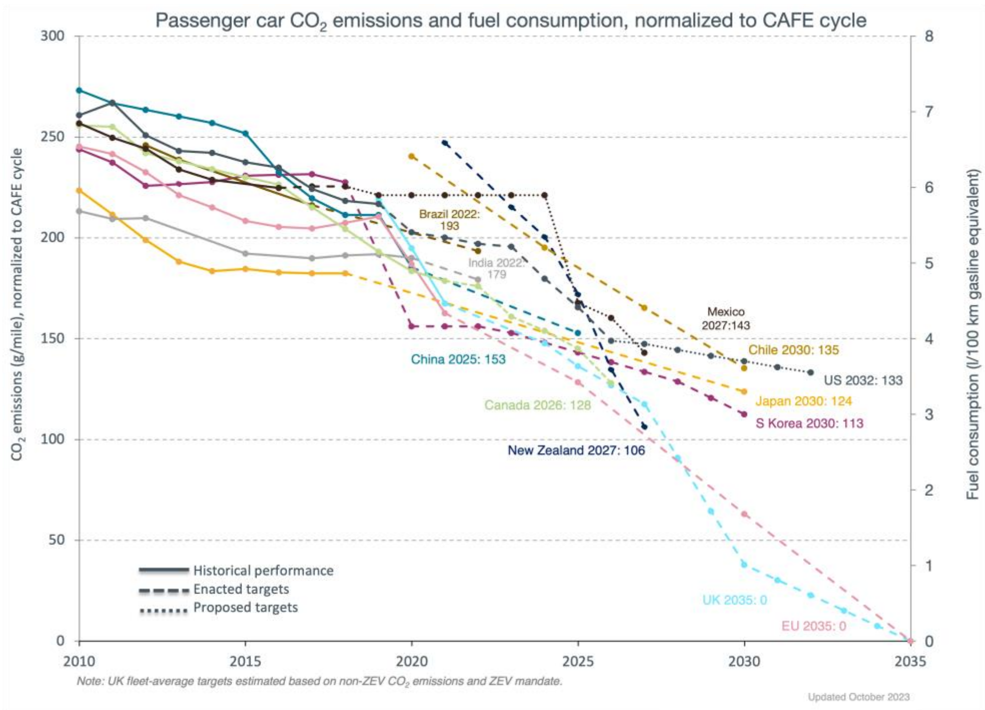


**Figure 2.** Global comparison of historical data and standards for passenger car $CO_2$ emissions and fuel consumption, normalized to CAFE cycle.

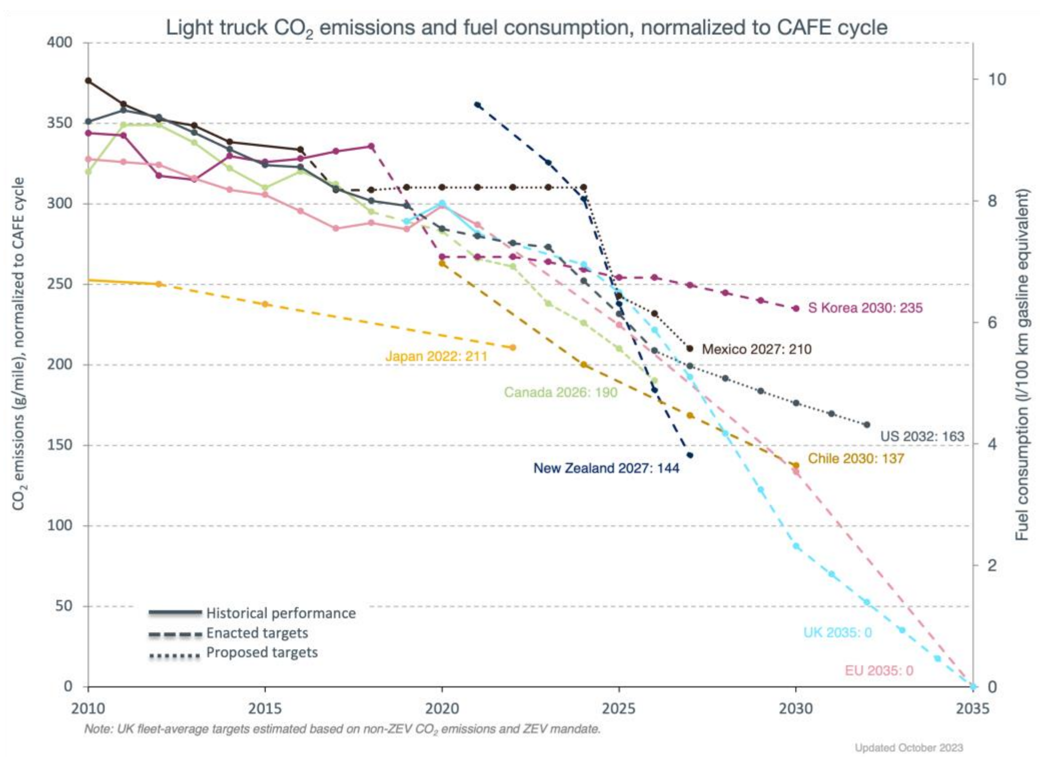

**Figure 3.** Global comparison of historical data and standards for light truck $CO_2$ emissions and fuel consumption, normalized to CAFE cycle.

The figures clearly show how the U.S. is not alone in its commitment to improving average new vehicle fuel economy. Many other jurisdictions including the European Union, the United Kingdom, Chile, New Zealand, Canada, South Korea, Japan, and several others have made great progress on improving fuel economy and have proposed or already enacted strong targets for greatly continued improvements.

## BATTERY ELECTRIC VEHICLE COST

While ICCT supports the proposed rule, we believe there is evidence available to support lower BEV costs than NHTSA has modeled, which further support the fact that NHTSA's estimates of battery-electric and plug-in hybrid electric vehicle penetration rates under the No Action and four "action" alternatives are reasonable and feasible. Electric vehicle and battery technology has been improving rapidly and technology costs have been greatly reduced. Automakers are investing heavily in BEV R&D and manufacturing capacity and are achieving higher production volumes with more advanced technologies at lower costs.

New 2022 ICCT research assessed light-duty electric vehicle costs and consumer benefits in the United States in the 2022-2035 time frame and found that without any federal, state, utility, or local incentives, BEV purchase price parity is coming before 2030 for BEVs with up to 300 miles of range across all light-duty car, crossover, SUV, and pickup truck classes.[40] Continued technological advancements and increased battery production volumes mean that pack-level battery costs are expected to decline to about $105/kWh by 2025 and $74/kWh by 2030. These developments are critical to achieving electric vehicle initial price parity with conventional vehicles, which the 2022 ICCT analysis finds to occur between 2024 and 2026 for 150- to 200-mile range BEVs, between 2027 and 2029 for 250- to 300-mile range BEVs, and between 2029 and 2033 for 350- to 400-mile range BEVs. These results—along with others discussed below—from ICCT's 2022 EV cost study are aligned with those found in similarly recent studies of EV cost parity.[41] The cost parity findings are further reinforced by new Energy Innovation and Consumer Reports research showing that in 2023 most new electric vehicles are already cheaper to own than gasoline-powered vehicles in the United States from day one.[42]

Table 2 summarizes the findings of the underlying technical specifications for 300-mile range BEVs in 2027, 2030, and 2032 in the ICCT analysis. The pack cost per kWh in the ICCT analysis do not include the 45X tax credit; applying the 45X tax credit to the ICCT battery costs would further reduce BEV costs. Although not shown, the initial 2022 BEV efficiencies in the ICCT study are based directly on existing MY 2022. BEV models and account for increased

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[40] Slowik. P., Isenstadt, A., Pierce, L, Searle, S. (2022). Assessment of light-duty electric vehicle costs and consumer benefits in the United States in the 2022-2035 time frame. *International Council on Clean Transportation.* https://theicct.org/publication/ev-cost-benefits-2035-oct22/

[41] H. Saxena, V. Nair, S. Pillai, "Electrification Cost Evaluation of Light-Duty Vehicles for MY 2030," 2023. Roush. https://www.edf.org/sites/default/files/2023-05/Electrification_Cost_Evaluation_of_LDVs_for_MY2030_Roush.pdf and Transport and Environment. (2021). Hitting the EV inflection point. Retrieved from https://www.transportenvironment.org/discover/hitting-the-ev-inflection-point/

[42] Orvis, R. (2022). Most electric vehicles are cheaper to own off the lot than gas cars. *Energy Innovation.* https://energyinnovation.org/wp-content/uploads/2022/05/Most-Electric-Vehicles-Are-Cheaper-Off-The-Lot-Than-Gas-Cars.pdf and Consumer Reports (2023). Electric vehicles save consumers money. https://advocacy.consumerreports.org/research/cr-fact-sheet-electric-vehicles-save-consumers-money/

electricity-per-mile for longer-range vehicles. Several high-volume MY 2022 models inform the initial 2022 average technical specifications for each class. Efficiency improves annually due to electric component (battery, motor, power electronic) and vehicle-level (mass reduction, aerodynamic, tire rolling resistance) improvements, and 2030 and beyond values are based on modeling by CARB (2022).[43] The 2030 efficiencies are somewhat better than those of the "Best in class" models from 2022.

**Table 2.** Summary of key BEV technical specifications in ICCT (2022)

| | | 2027 | 2030 | 2032 |
|---|---|---|---|---|
| Pack size (kWh) | Car | 71 | 64 | 63 |
| | Crossover | 78 | 67 | 67 |
| | SUV | 93 | 82 | 81 |
| | Pickup | 117 | 104 | 103 |
| On-road efficiency (kWh/mile) | Car | 0.24 | 0.22 | 0.22 |
| | Crossover | 0.27 | 0.24 | 0.23 |
| | SUV | 0.32 | 0.28 | 0.28 |
| | Pickup | 0.40 | 0.36 | 0.36 |
| Pack cost ($/kWh) | Car | 87 | 71 | 65 |
| | Crossover | 86 | 71 | 65 |
| | SUV | 84 | 69 | 63 |
| | Pickup | 82 | 67 | 61 |
| Total pack cost (kWh * $/kWh) | Car | $6,224 | $4,549 | $4,097 |
| | Crossover | $6,766 | $4,783 | $4,308 |
| | SUV | $7,851 | $5,648 | $5,087 |
| | Pickup | $9,564 | $6,983 | $6,290 |

*Note. Numbers in table are rounded*

The ICCT conducted a thorough battery cost review and applied the best available data and analysis of current and future electric vehicle and battery technical specifications.[44] Figure 4 shows the ICCT's 2022 battery cost review, which was based on expert sources, research literature projections, and automaker announcements. Our battery cost review includes the most recent projections by expert sources including the California Air Resources Board (2022), Roush Industries Inc. (see Saxena, Stone, Nair, & Pillai, 2023), Bloomberg New Energy Finance (2020, 2021), UBS (2020) and technical research studies, including Mauler, Lou, Duffner, and Leker (2022), Nykvist, Sprei, and Nilsson (2019), Penisa et al. (2020), Hsieh, Pan, Chiang, and Green (2019), and Berckmans et al. (2017). The automaker announcements shown include Volkswagen for $135 per kilowatt-hour in 2021–2022 (Witter, 2018), Tesla for $55/kWh in 2025 (Tesla, 2020), and Renault and Ford for $80/kWh in 2030 (Automotive News, 2021a, 2021b; Ford, 2021). Not shown due to uncertainties related to timing, General Motors in 2020 announced continued improvements toward below $100/kWh at the cell level, and Volkswagen in 2021 announced developments toward "significantly below" $100/kWh at the pack-level

[43] California Air Resources Board. (2022). Advanced Clean Cars II Rulemaking: ZEV Cost Modeling Workbook March 2022. https://ww2.arb.ca.gov/our-work/programs/advancedclean-cars-program/advanced-clean-cars-ii

[44] Slowik. P., Isenstadt, A., Pierce, L, Searle, S. (2022). Assessment of light-duty electric vehicle costs and consumer benefits in the United States in the 2022-2035 time frame. *International Council on Clean Transportation.* https://theicct.org/publication/ev-cost-benefits-2035-oct22/

(General Motors, 2020; Volkswagen, 2021).[45] These costs refer to the battery pack cost as seen by a manufacturer of light-duty vehicles and are thus considered direct manufacturing costs.

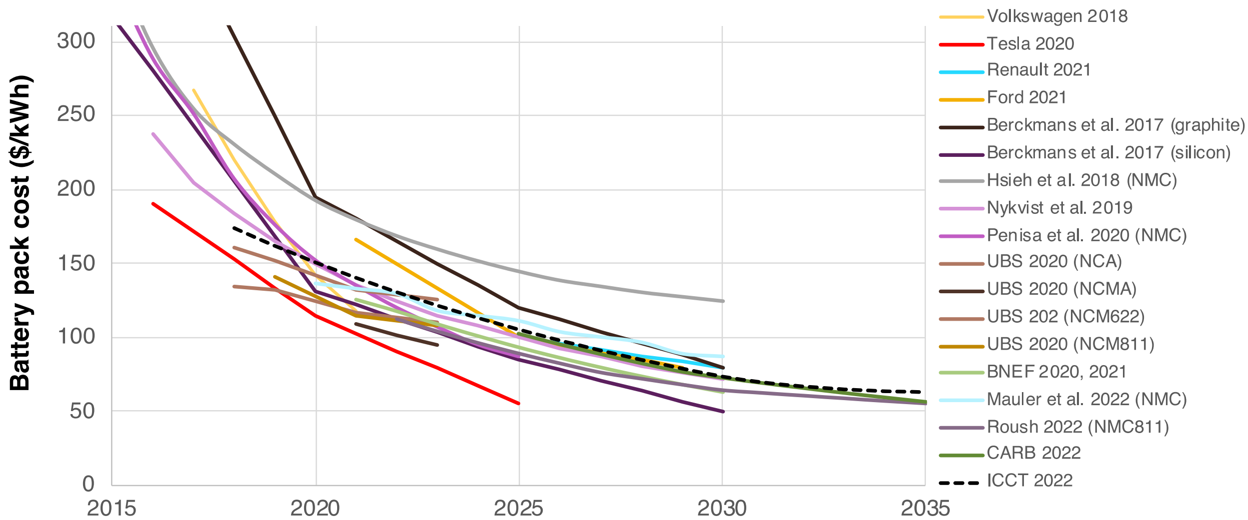


**Figure 4.** Electric vehicle battery pack costs from technical studies and automaker statements

Very recent BEV-related automaker announcements and developments from automotive suppliers reflect the continued rapid pace of innovation in BEV technologies. For example, Toyota recently announced its 2026 plans to produce battery packs capable of over 600 miles of range at lower cost than its current packs.[46] Toyota also plans to produce solid-state battery packs with 20%-50% more range, and bipolar lithium iron phosphate packs at 40% lower cost starting around 2028.[47] Beyond reducing costs through battery improvements and vehicle efficiency increases, Toyota plans to reduce vehicle manufacturing costs through improvements in factory operation, giga-casting to reduce parts and complexity, and reduced development times.[48] Similarly, Volvo announced its plans to reduce EV costs through cell-to-body battery packaging, integrated motor, inverter, transmission units, and giga-castings.[49] Meanwhile, the advent of two-speed transmissions for BEVs from automotive suppliers increases motor efficiency and performance, allowing battery and motor downsizing.[50] Another supplier innovation that improves EV efficiency especially for induction motors is Tula's Dynamic Motor Drive.[51] Still other areas of innovation include higher voltage EV platforms, axial flux motor

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[45] Complete referencing is available at https://theicct.org/publication/ev-cost-benefits-2035-oct22/

[46] Greimel, H. (2023, June 12). Newly revealed Toyota EV plans include batteries with 900-plus miles of range." *Automotive News*. https://www.autonews.com/mobility-report/toyota-future-ev-plans-include-batteries-900-mile-range

[47] Ibid.

[48] Ibid.

[49] Karkaria, U. (2023, June 14). Volvo EX30 electric crossover will approach price parity. *Automotive News*. https://www.autonews.com/retail/how-volvos-electric-ex30-crossover-will-approach-price-parity

[50] Brooke, L. (2021, February). Gearing EVs for greater efficiency." *SAE Automotive Engineering*. https://www.nxtbook.com/smg/sae/21AE02/index.php#/p/16

[51] Wolfe, M. (2022, December). Tula's DMD promises gains in EV efficiency. *SAE Automotive Engineering*. https://www.nxtbook.com/smg/sae/22AE12/index.php#/p/14

improvements, and current-source inverters.[52] These recent examples go beyond the technology improvements assumed in the 2022 ICCT EV cost study.

## COMBUSTION VEHICLE EFFICIENCY POTENTIAL AND COST-EFFECTIVENESS

While ICCT supports the proposed rule, the cost of compliance may be overstated due to the use of outdated internal combustion engine vehicle (ICEV) technology data and information. ICEV technology has been consistently improving for decades. While automakers are investing heavily in BEV development, the substantial progress that has been—and continues to be—made in ICE technology has yet to saturate the market. That is, many existing and recently announced ICEV technology improvements have ample room for increased application throughout the ICEV fleet. As many ICE vehicles are still to be sold in the MY2027-2032 timeframe, the proposed rule is an opportunity to maximize their efficiency and minimize their tailpipe emissions, while providing substantial consumer fuel savings.

ICCT commented extensively on recent ICEV technology improvements in its 2018 comments on the SAFE NPRM for 2021-26 cars and light trucks (ICCT 2018 comments)[53], its study of LPM and OMEGA modeling of the 2018 Camry (ICCT 2018 Camry)[54], its supplemental comments responding to Toyota comments on ICCT's study of LPM and OMEGA modeling of the 2018 Camry (ICCT 2019 comments)[55], and its 2021 comments on the Revised Corporate Average Fuel Economy Standards for Model Years 2024-2026 Passenger Cars and Light Trucks (ICCT 2021 comments).[56] Much of the content of these prior comments are reiterated or summarized in the following subsections, as appropriate and relevant for this proposed rule. Moreover, recent reports demonstrate that further technology improvements are coming that can boost ICE vehicle efficiency levels well beyond that of even the highly-efficient high-compression ratio Atkinson cycle engine efficiency levels assumed in this proposal,[57,58] as well as show the declining costs of 48-volt mild hybrid systems.[59,60]

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[52] Madasamy, K. (2023, May 7). Guest commentary: The next frontier of EV innovation: The powertrain. *Automotive News*. https://www.autonews.com/guest-commentary/ev-powertrain-next-frontier-innovation

[53] ICCT Comments on the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Truck. (2018, October 26). https://theicct.org/news/comments-safe-regulation-2021-2026 (ICCT 2018 comments)

[54] German J. (2018, February 21). How things work: OMEGA modeling case study based on the 2018 Toyota Camry. https://theicct.org/publications/how-things-work-omega-modeling-case-study-based-2018-toyota-camry (ICCT 2018 Camry)

[55] Supplemental Comment from the International Council on Clean Transportation. (2019, April 28). Docket #NHTSA-2018-0067-12387. https://www.regulations.gov/comment/NHTSA-2018-0067-12387, #NHTSA-2018-0067-12388 https://www.regulations.gov/comment/NHTSA-2018-0067-12388 (ICCT 2019 comments)

[56] ICCT comments on the Revised Corporate Average Fuel Economy Standards for Model Years 2024-2026 Passenger Cars and Light Trucks. (2021, October 26). Docket ID NHTSA-2021-0053, https://www.regulations.gov/docket/NHTSA-2021-0053, Comment ID NHTSA-2021-0053-1581, https://www.regulations.gov/comment/NHTSA-2021-0053-1581 (ICCT 2021 comments)

[57] AVL Webinar on Passenger Car powertrain 4.x – Fuel Consumption, Emissions, and Cost. (2020, June 2). https://www.avl.com/-/passenger-car-powertrain-4.x-fuel-consumption-emissions-and-cost (Slides available at https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0522) (AVL 2020)

[58] Roush report on Gasoline Engine Technologies for Improved Efficiency (Roush 2021 LDV) https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0210

[59] Roush report on 48V and BEV costs (Roush 2021 48V) https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0210

[60] Dornoff, J., German, J., Deo, A. (ICCT), Dimaratos, A. (DITENCO). (2022). Mild-hybrid vehicles: a near term technology trend for $CO_2$ emissions reduction. https://theicct.org/publication/mild-hybrid-emissions-jul22/ (ICCT 2022 MHEV)

As documented in the following subsections, the efficiency potential of ICE technology has continued to improve, while costs have remained lower than previously estimated. Thus, if technology costs and benefits were updated with the latest information, it would show that the proposed standards are even more feasible and lower-cost than NHTSA's analysis indicates. The following subsections discuss these various updated ICE technologies.

## Summary of previously submitted technology assessments

We present here a summary of previously submitted comments, as these remain largely, if not entirely, relevant to the current proposed rule.

**Outdated engine maps**
Although NHTSA scales its MY2010 hybrid Atkinson engine map to match the thermal efficiency of the MY2017 Toyota Prius, this appears to have been the only update made to the several engine maps that underpin all base and advanced engine technologies. The remaining engine maps are still primarily based on outdated engines (e.g., from MY2011, 2013 and 2014 vehicles). Even with the updated hybrid engine, the newest Toyota Prius demonstrates an additional 10% improvement over the outgoing variant, due in part to improvements in engine efficiency.[61] For additional information, see ICCT 2021 comments page 3-4.

**Turbocharging effectiveness**
EPA added a 2nd generation turbocharged downsized engine package based on EPA benchmark testing of the Honda L15B7 1.5L turbocharged, direct-injection engine to its 2018 mid-term evaluation, which was not used in NHTSA's proposed rule.[62]

**HCR engine effectiveness**
EPA added an engine map in its 2018 mid-term evaluation for Atkinson (ATK2+CEGR) technology based on EPA benchmark testing of the MY2018 Camry 2.5L A25A FKS engine. However, NHTSA's proposed rule appears to continue to use developmental engine test data and GT-POWER engine modeling.[63]

**Cylinder Deactivation on Turbocharged Vehicles and HCR engines**
The modeled benefit of adding cylinder deactivation (DEAC) to turbocharged and HCR engines appears to be only about 25% of the benefit of adding DEAC to the base engine.[64] While DEAC added to turbo or HCR engines will have lower pumping loss reductions than when added to base naturally aspirated engines, DEAC can still be expected to provide significant pumping loss reductions while enabling the engine to operate in a more thermally efficient region of the engine map. For additional information, see ICCT 2021 comments page 5.

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[61] COMMENTS BY JOHN GERMAN AND JOHN D. GRAHAM ON EPA'S NPRM CONTAINING NEW CO2 STANDARDS FOR LIGHT-DUTY AND MEDIUM-DUTY VEHICLES, MODEL YEARS 2027-2032 (2023, July 5). Docket ID No. EPA–HQ– OAR–2022–0829. Comment ID EPA-HQ-OAR-2022-0829-0585. https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0829-0585

[62] Stuhldreher, M., Kargul, J., Barba, D., McDonald, J., Bohac, S., Dekraker, P., & Moskalik, A. (2018). Benchmarking a 2016 Honda Civic 1.5-liter L15B7 turbocharged engine and evaluating the future efficiency potential of turbocharged engines. SAE International journal of engines, 11(6), 1273.

[63] Kargul, J., Stuhldreher, M., Barba, D., Schenk, C., Bohac, S., McDonald, J., & Dekraker, P. (2019). Benchmarking a 2018 Toyota Camry 2.5-liter Atkinson Cycle Engine with Cooled-EGR. SAE International Journal of Advances and Current Practices in Mobility, 1(2), 601.

[64] Draft Technical Support Document Figure 3-10

**Engine downsizing and secondary mass reduction restrictions**
For this proposal, NHTSA continues to only downsize engines for large changes in tractive load. As commented previously, this artificially increases the overall performance of the fleet, the consumer benefits of which the proposed rule does not address. ICCT recommends to always model the appropriate amount of engine downsizing to maintain performance. For additional information, see ICCT 2021 comments page 5.

**Strong hybrid**
As mentioned earlier, NHTSA relies on hybrid engine effectiveness that may already be outdated compared to what is currently available on the market. Moreover, NHTSA assumes no additional hybrid powertrain improvements. This is unrealistic, as, for example, every subsequent generation of Toyota's hybrid system significantly improves upon the prior generation's efficiency.[65] ICCT recommends NHTSA include at least one future hybrid system improvement beyond that which is already modeled. ICCT also recommends NHTSA allow hybridization on all vehicle types, as well as carefully consider updated costs. Additional information on hybrid system costs, effectiveness, and applicability can be found in ICCT 2021 comments, pages 21-25.

## New technology studies

As mentioned previously, several new studies describe promising technology trends that have yet to be incorporated into NHTSA's modeling of the proposed standards (footnoted above: AVL 2020, Roush 2021 LDV, Roush 2021 48V, ICCT 2022 MHEV).

**48V Mild Hybrids (MHEV)**
ICCT estimated the cost of position 0 (P0) MHEV systems in 2016[66] and more recently in 2022[67], finding substantial reductions in cost. These costs are presented in Table 3. Alongside ICCT's estimates are those from NHTSA used in this proposal.[68] As the table clearly shows, proposed MHEV costs are higher than ICCT's current estimates. These higher costs appear to be due to higher component cost per kW or cost per kWh. If NHTSA P0 MHEV costs were scaled up to match the specifications of ICCT's P0 system, the NHTSA costs would be even higher. ICCT believes that NHTSA could reduce its P0 MHEV costs accordingly.

**Table 3.** Comparison of NHTSA, ICCT 2016 and 2022 P0 mild hybrid (MHEV) direct manufacturing costs

| P0 MHEV cost component | Proposal (MY2022) | ICCT 2022 (2021 USD) | ICCT 2016 (2019 USD) |
|---|---|---|---|
| battery (kWh) | 0.403 | 0.53 | 0.53 |
| power (kW) | 10 | 15 | 15 |

[65] COMMENTS BY JOHN GERMAN AND JOHN D. GRAHAM ON EPA'S NPRM CONTAINING NEW CO2 STANDARDS FOR LIGHT-DUTY AND MEDIUM-DUTY VEHICLES, MODEL YEARS 2027-2032 (2023, July 5). Docket ID No. EPA–HQ– OAR–2022–0829. Comment ID EPA-HQ-OAR-2022-0829-0585. https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0829-0585

[66] Isenstadt, A., German, J. (ICCT), Dorobantu, M. (Eaton), Boggs, D. (Ricardo), Watson, T. (JCI). (2016). Downsized, boosted gasoline engines. https://theicct.org/publication/downsized-boosted-gasoline-engines-2/

[67] Dornoff, J., German, J., Deo, A. (ICCT), Dimaratos, A. (DITENCO). (2022). Mild-hybrid vehicles: a near term technology trend for $CO_2$ emissions reduction. https://theicct.org/publication/mild-hybrid-emissions-jul22/ (ICCT 2022 MHEV)

[68] Draft TSD Table 3-88, total costs in Table 3-88 have been divided by the RPE (1.5) to compare with ICCT's direct costs.

| | | | |
|---|---|---|---|
| Non-battery component | | | |
| Motor + Inverter | component costs not estimated | component costs not estimated | $300 |
| Alternator ** | | | -$65 |
| DC-DC converter | | | $150 |
| HV cables | | | $0 |
| brakes & actuators | | | $78 |
| Non-battery subtotal | $418 | $340 | $462 |
| Battery subtotal | $283 | $331 | $449 |
| Total | $701 | $671 | $911 |

** Alternator removal costs represented by negative cost (cost savings)

For further information, see Dornoff, J., German, J., Deo, A. (ICCT), Dimaratos, A. (DITENCO). (2022). *Mild-hybrid vehicles: a near term technology trend for $CO_2$ emissions reduction*. https://theicct.org/publication/mild-hybrid-emissions-jul22/ and
Isenstadt, A., German, J. (ICCT), Dorobantu, M. (Eaton), Boggs, D. (Ricardo), Watson, T. (JCI). (2016). *Downsized, boosted gasoline engines*. https://theicct.org/publication/downsized-boosted-gasoline-engines-2/

Beyond P0 MHEV architectures, there are substantial fuel savings benefits achievable by implementing P1-P4 architectures, representing placement of the motor/generator in positions of increasing distance from the engine along the driveline. While such systems cost more than P0, they are more cost-effective in that they have lower cost per percent reduction in fuel consumption. Thus, ICCT finds that NHTSA could consider including in its modeling more advanced MHEV architectures beyond P0.

Table 4 below replicates Table 18 in ICCT 2022 MHEV. As shown in the table, P1-P4 MHEV architectures with specifications similar to P0 MHEV can increase cost by at most 53% (P4+P0 for FWD) with P4+P0 for AWD *decreasing* costs vs P0. At the same time, P2-P4 architectures can more than double P0 effectiveness.

**Table 4.** Mild hybrid architecture cost in 2020 (ICCT 2022 MHEV, Table 18)

| Architecture | System specifications | | Cost normalized to P0 | | | Effectiveness | |
|---|---|---|---|---|---|---|---|
| | Motor | Battery | Battery | Non-battery | Total | WLTP $CO_2$ reduction | Cost per % $CO_2$ reduction normalized to P0 |
| P0 | 16 kW | 800 Wh | 1.00 | 1.00 | 1.00 | 6.6% | 1.00 |
| P1 | 15 kW | 800 Wh | 1.00 | 1.29 | 1.15 | 8.5% | 0.89 |
| P2 side mounted | 16 kW | 800 Wh | 1.00 | 1.51 | 1.27 | 11.9% | 0.70 |
| P2 coaxial | 15 kW | 800 Wh | 1.00 | 1.62 | 1.32 | 14.8% | 0.59 |
| P3 | 16 kW | 800 Wh | 1.00 | 1.65 | 1.34 | 15.3% | 0.58 |
| P4+P0 vs. FWD | 15 kW+4kW | 800 Wh | 1.00 | 2.01 | 1.53 | 15.5% | 0.65 |
| P4+P0 vs. AWD | 15 kW+4kW | 800 Wh | 1.00 | 0.82 | 0.91 | 23.9% | 0.25 |

For further information, see Dornoff, J., German, J., Deo, A. (ICCT), Dimaratos, A. (DITENCO). (2022). Mild-hybrid vehicles: a near term technology trend for $CO_2$ emissions reduction. https://theicct.org/publication/mild-hybrid-emissions-jul22/

Outlined in the table above, MHEV architectures beyond P0 can have substantial fuel savings benefits. However, the benefits of more advanced MHEV architectures are expected to exceed those illustrated in the table, through the implementation of higher power systems (20kW-30kW). Roush 2021 LDV[69] describes the additional benefits offered by higher power MHEV systems, including advancements in electric boosting, high energy ignition systems (see section below), accessory electrification, and electrically heated catalysts. Enabling electrically heated catalysts in particular permits further fuel economy optimization through, for example, aggressive stop-start strategies.

For additional information, see:
- Roush 2021 LDV page 11 and pages 38-40
- Roush 2021 48V[70] pages 11-23
- AVL 2020 slide 62[71]

Roush 2021 LDV provides specific example applications of high power MHEV systems and the associated fuel efficiency improvements on pickups and SUVs. These examples, which have not previously been considered by either NHTSA or ICCT, are excerpted below:

*Pickup/full-size SUV GHG reduction*: As ICCT previously commented, Roush 2021 states "Two powertrain configurations are recommended for study and could support future rulemaking. The first option synergistically combines available technologies (without a major redesign of the underlying engine architecture) to give maximum fuel economy benefit for a relatively low cost, hence high effectiveness. It combines a naturally aspirated DI engine with advanced cylinder deactivation and a 30kW 48V P2 mild hybrid system. The 48V hybrid system is used to actively smooth out crankshaft torque pulsations to enable aggressive cylinder deactivation strategies (advanced deac – like the Tula Skipfire System). Such a system will also enable start-stop, electric creep, regen braking, slow-speed electric driving, and a heated catalyst. Depending on system integration factors Roush estimates a reduction in GHG emissions of 20% or more, compared to a baseline naturally aspirated direct-injection V8." (Roush 2021 LDV page 13). Additional information can be found at:
- Roush 2021 LDV Section 13.1 page 65

*Compact SUV GHG Reduction*: Relatedly, as ICCT previously commented, Roush 2021 states, "A 30kW 48-volt P2 system mated to a low bore-to-stroke ratio Miller cycle engine with electrified boosting, advanced cylinder deactivation, cooled EGR and a heated catalyst can provide a fuel economy benefit close to a full high voltage hybrid powertrain at a much lower cost. The 48V electric motor can supplement the engine torque under low- speed high load conditions, thereby avoiding this knock-prone area of the engine map. Also, the use of an advanced boosting system, combining a turbocharger and a 48V electric supercharger, will reduce engine backpressure (larger turbine) and improve scavenging, reduce combustion residuals, and reduce the propensity for knock. This combination enables the use of a higher compression ratio, thereby increasing engine efficiency. A combination of a high-energy ignition system (high energy spark plug/plasma ignition) and fuel reforming by pilot fuel injection during

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[69] Roush report on Gasoline Engine Technologies for Improved Efficiency (Roush 2021 LDV) https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0210

[70] Roush report on 48V and BEV costs (Roush 2021 48V) https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0210

[71] AVL Webinar on Passenger Car powertrain 4.x – Fuel Consumption, Emissions, and Cost. (2020, June 2). https://www.avl.com/-/passenger-car-powertrain-4.x-fuel-consumption-emissions-and-cost (Slides available at https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0208-0522) (AVL 2020)

NVO can be used to increase cEGR tolerance at low loads. The initial part of such a project would include engine and combustion modeling, followed by prototype engine testing. The overall GHG reduction potential will require modeling and optimization of engine design, calibration parameters, and boosting system sizing and control. Roush estimates a reduction in GHG emissions exceeding 30% is possible compared to a level 1 (NHTSA) turbocharged engine." (Roush 2021 LDV page 14).
Additional information can be found at:

- Roush 2021 LDV Section 2.3 pages 23-25 on higher compression ratios and higher Miller/Atkinson ratios.
- Roush 2021 LDV Sections 2.4 and 2.5 pages 26-28 on low bore-to-stroke ratio benefits
- Roush 2021 LDV Section 13.2 page 66

**Dedicated hybrid engines**
In addition to ICCT's recommendation for improved future hybrid system efficiency, ICCT finds that NHTSA could consider even further optimized/efficient *dedicated* hybrid engines, both for HEV applications and for PHEVs. Due to the capacity of hybrid vehicles' (HEV) electric motor to take up low-speed, high torque demand and transient response, HEV engines can be optimized to a narrower operating range than non-HEV engines. This can enable higher compression ratios, increase EGR dilution, and potentially decrease costs. Especially in the case of a serial hybrid or range-extended PHEV, the engine is effectively decoupled from the drivetrain, permitting deep optimization, with up to 40% engine cost reduction depending on electrification.[72]

As described in ICCT's 2021 comments and in SAE (2021),[73] NHTSA should consider "the expanded application of energy management capabilities in full hybrid powertrains to also minimize operation under the low-speed high torque areas of the engine which are prone to knocking by torque augmentation with the electric motor. The instantaneous torque capability of the electric motor can effectively support transient torque demand. This will allow both naturally aspirated and turbocharged engines that are part of a hybrid powertrain to be optimized for a narrow operating range incorporating higher compression ratios and increased EGR dilution (maintaining stoichiometric operation), thereby prioritizing efficiency over peak torque at low engine speeds and transient response." (Roush 2021 LDV page 12)
For additional information, see:

- Roush 2021 LDV Section 7.0 pages 41-44
- AVL 2020 slide 24: BSFC for Lambda=1
- AVL 2020 slides 25-26: Dedicated Hybrid Engine Efficiency Roadmaps (45% Lambda=1, 51% ideal)
- AVL 2020 slides 35-42: WLTP CO2 reduction potential of various hybrid configurations
- AVL 2020 slide 43: Relative comparison of attributes for three powertrain architectures
- AVL 2020 slide 62: WLTP % CO2 reduction and slide 63: cost per % FC reduction

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[72] SAE 2021. (2021). Optimizing hybrids for cost and efficiency. *SAE Automotive Engineering*. Page 18. https://www.nxtbook.com/smg/sae/21AE04/index.php#/p/18
[73] Ibid.

Such dedicated hybrid engines can achieve 45% brake thermal efficiency (BTE) at stoichiometric air-fuel ratio using known technologies,[74] or 50% BTE in a serial/range-extender with pre-chamber ignition, ultra-high pressure injection, and reduced intake air temperatures (SAE 2021).

**Negative valve overlap in-cylinder fuel reforming (NVO)**
As ICCT previously commented, Roush states, "In-cylinder fuel reforming by using pilot fuel injection during NVO has shown to significantly improve cooled EGR (cEGR) tolerance, combustion stability, and engine efficiency. Such a system can have wide application in turbocharged and NA engines across different vehicle segments with minimal hardware requirements. Depending on the base engine, Roush estimates an efficiency improvement…in the range of 5 to 10% is possible and low cost, therefore correspondingly high effectiveness." (Roush 2021 LDV page 14).
Additional information can be found at:

- Roush 2021 LDV Section 10.0 pages 50-52
- Roush 2021 LDV Section 13.3 page 66

**Passive prechamber combustion (PPC)**
As ICCT previously commented, Roush states, "Prechamber combustion systems are one of the most promising technologies for improving the dilution limit of engines, thereby improving system efficiency. It can also enable extremely fast burn rates increasing the knock tolerance of turbocharged engines, allowing higher compression ratios and the associated efficiency improvements. The Maserati Nettuno engine in the 2021 Maserati MC20 will be the first application of a passive prechamber engine in production. However, the primary objective in the MC20 is high performance. It would be very valuable to study the effect of the system on knock tolerance, burn rates, dilution tolerance (EGR and air), and emissions. The effort should focus on quantifying possible efficiency gains in a non-performance application." (Roush 2021 LDV pages 14-15). In a dedicated hybrid engine developed by Mahle, pre-chamber combustion enabled an efficiency improvement of over 5%.[75]
Additional information can be found at:

- Roush 2021 LDV Section 13.4 page 67
- AVL 2020 slides 28, 31, and 33

**High energy ignition (HEI)**
As ICCT previously commented, Roush states, "High energy volume ignition systems can enable combustion of dilute (cEGR or air diluted) in-cylinder mixtures resulting in a step-change in engine efficiency compared to conventional spark plugs. Such systems can be a drop-in replacement for a spark plug, thereby representing a cost-effective GHG improvement option. Such systems should be evaluated for maximum efficiency potential, in conventional, 48V mild hybrid, and full HV hybrid applications. Roush estimates that systems such as plasma ignition can support good combustion stability with high amounts of cooled EGR, thereby achieving engine efficiency improvements in the range of 5-10% over a baseline turbocharged DI, dual VVT engine. Microwave ignition systems, on the other hand, have the potential to achieve levels consistent with prechamber ignition systems. This would enable lean-burn engines with low engine-out NOx emissions which can achieve brake thermal efficiency which exceeds 45% in

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[74] Visnic, B. (2022, April). Keeping combustion in the conversation. *SAE Automotive Engineering*. Page 18. https://www.nxtbook.com/smg/sae/22AE04/index.php#/p/18
[75] Birch, S. (2019, November). Mahle reveals modular, scalable integrated hybrid powertrain. *SAE Automotive Engineering*. Page 14. https://www.nxtbook.com/nxtbooks/sae/19AUTP11/index.php#/p/14

light-duty vehicle applications, compared to a level of 36-38% for a baseline turbocharged DI, dual VVT engine." (Roush 2021 LDV page 15). Additional information can be found at:

- Roush 2021 LDV Section 11.0 pages 53-62
- Roush 2021 LDV Section 13.5 page 67

## Atkinson cycle engine restrictions (HCR, HCRE, HCRD)

NHTSA inappropriately prevents the application of HCR engines on engines with more than 405 horsepower, pickup trucks and vehicles that share engines with pickup trucks, or performance-focused manufacturers.[76]

As discussed in ICCT 2021 comments, engines in pickup trucks and high-performance vehicles are sized and powered to handle higher peak loads. This means larger engines operate at lower loads relative to their maximum capacity on the 2-cycle test – and during most real-world driving. This, in turn, means that pickup trucks and high-performance vehicles will spend more time in Atkinson Cycle operation than lower performance vehicles on both the test cycles and in the real world. This includes time spent towing, which represents a very small fraction of light-duty pickup usage.[77,78] Altogether, most light-duty pickup trucks spend the vast majority of driving at low loads relative to the engine's capability, where Atkinson Cycle engines are very effective. In other words, HCR is likely a highly cost-effective technology for pickup trucks. Furthermore, the claim that an Atkinson Cycle engine that switches to Otto cycle on demand cannot provide the additional torque reserve is not accurate (a claim previously used to justify blocking HCR on pickups in prior rulemakings, see ICCT 2021 comments).

Moreover, Atkinson Cycle engines have been used on the Toyota Tacoma pickup V6 engine since 2017, illustrating that Atkinson Cycle engines are cost-effective for use on pickups.

For additional information see:

- ICCT 2021 comments pages 25-28
- ICCT 2018 comments pages I-2–I-12
- ICCT 2018 Camry study

## Potential technology penetration impacts of improved ICE technology adoption

With the above findings regarding ICE technology costs and effectiveness, potential implementation of such technology on the MY2027-2032 ICEV fleet can result in significant improvements in fuel economy from ICE vehicles. In its study of updated light-duty vehicle costs,[79] ICCT assumed updated ICE technology adoption as described above would continue to provide ICEV improvement equivalent to 3.5% per year through at least 2032. Fuel savings with that level of improvement more than offset incremental technology cost. Starting from a 2022 fuel economy value of 27 mpg, the overall real-world efficiency of the combustion light-duty

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[76] Draft TSD, Section 3.1.3.3, page 3-26

[77] Berk, B. (2019, March 13). You Don't Need a Full-Size Pickup Truck, You Need a Cowboy Costume. *Thedrive.com.* https://www.thedrive.com/news/26907/you-dont-need-a-full-size-pickup-truck-you-need-a-cowboy-costume

[78] Chase, W., Whalen, J., Muller, J. (2023, January 23). Pickup Trucks: from workhorse to joyride. *Axios*. https://www.axios.com/ford-pickup-trucks-history

[79] Slowik. P., Isenstadt, A., Pierce, L, Searle, S. (2022). Assessment of light-duty electric vehicle costs and consumer benefits in the United States in the 2022-2035 time frame. *International Council on Clean Transportation*. https://theicct.org/publication/ev-cost-benefits-2035-oct22/

vehicle fleet was 32 mpg in 2027 and 36 mpg in 2030 and 39 mpg in 2032. In total, over MY2027-2032, the net reduction in ICE fuel consumption is 16.4%. However, greater market penetration of P0-P4 MHEV, conventional strong HEV and dedicated HEV, among other technologies, can lead to even larger reductions in fuel consumption, on the order of 5% per year over the timeframe of the proposed rule. Moreover, given market readiness for and automaker announcements of electric vehicles, we project future EV share to exceed that modeled by NHTSA within 2027-2032 (see Figure 1), making the proposed fuel economy standards even more feasible.

ICCT supports the proposed standards and recommends its finalization as quickly as possible. Our research shows that the proposed standards are likely less costly than estimated and can be met with a variety of technological approaches and pathways, evidenced ICE technology updates discussed above. Furthermore, our analysis of market readiness and detailed BEV cost analysis support NHTSA's estimates of battery-electric and plug-in hybrid electric vehicle penetration rates under the No Action and four "action" alternatives, which we find to be reasonable and achievable.

## OFF-CYCLE CREDITS

ICCT strongly supports NHTSA's proposals to update its air-conditioning (AC) and off-cycle (OC) credit programs.

Specifically, ICCT supports NHTSA limiting OC and AC credits to ICEVs, as the credits are based on ICE fuel consumption reductions. While BEVs also benefit from improved AC system efficiency and off-cycle technologies, BEVs do not require the additional incentive provided by AC and OC credits. BEVs already are granted compliance fuel consumption values above any ICEV, and advances in AC efficiency and off-cycle (i.e., real world) efficiency are inherent to BEV development, as passenger and battery heating/cooling loads and real-world driving efficiency can significantly impact BEV range and battery size requirements. Relatedly, ICCT supports the proposal to scale PHEV OC and AC credits by the utility factor.

ICCT supports the proposal to phaseout OC credits by MY2031, and to eliminate the off-menu OC credit option starting MY2027. A large portion of the fleet already incorporates the technologies that are granted OC credits. According to the 2022 Automotive Trends Report data, MY2021 cars averaged 5.1 g/mi in OC credits (51% of the 10 g/mi cap) and trucks averaged 10.2 g/mi in OC credits (102% of the 10 g/mi cap).[80] With these averages as a proxy for the share of the car and truck fleets with OC technology, OC technology is already widespread in the baseline and requires no further incentivization. Evidence suggests that the menu OC credit values (such as solar and thermal load control) overestimate the real-world impact of OC technologies.[81] Moreover, the menu credits are defined in terms of absolute g/mi reductions, rather than relative or percentage-based reductions, as virtually all on-cycle technologies are defined (and measured). Because of this inappropriate definition, as vehicles become increasingly efficient, these absolute credit values represent unrealistically large shares of vehicles' overall efficiency improvement. While ICCT recommends NHTSA simply phaseout

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[80] EPA. (2022). Automotive Trends Report [data]. https://www.epa.gov/automotive-trends/explore-automotive-trends-data

[81] Lutsey, N., Isenstadt, A. (2018). How will off-cycle credits impact U.S. 2025 efficiency standards? *International Council on Clean Transportation.* https://theicct.org/publication/how-will-off-cycle-credits-impact-u-s-2025-efficiency-standards/

OC credits altogether, if NHTSA decides to introduce *new* OC credits for ICEVs, they should be calculated as a relative, or percentage based.

Additionally, as OC credits are based on reduced fuel consumption from ICE vehicles, they are not applicable to BEVs. As with AC efficiency improvements, any innovation that reduces real world energy consumption in BEVs is inherently incentivized by the reduced battery capacity requirements of incorporating such innovations. Thus, ICCT recommends NHTSA *not* introduce new OC and AC credits for BEVs. If NHTSA decides to introduce such credits, they should be based on relative or percentage-based reductions in 5-cycle energy consumption.

## PLUG-IN HYBRID ELECTRIC VEHICLES

For its compliance modeling, ICCT supports NHTSA using the proposed PHEV utility factor (UF) curve developed by EPA. This newly proposed UF curve is based on real-world PHEV usage data aligned with ICCT research.[82]

## HEAVY-DUTY PICKUP TRUCKS AND VANS FOR MODEL YEARS 2030-2035

ICCT supports NHTSA's proposed standards for heavy-duty pickup trucks and vans and believes that the costs may be lower than modeled. Many gasoline and diesel efficiency-improving technologies have yet to be broadly implemented among heavy-duty pickup trucks and vans. In particular, many LD-related technologies like those discussed in previous sections in these comments can be applied to several heavy-duty pickup trucks and vans. For instance, strong and mild hybrid systems that are well-suited for full-size LD SUVs and pickups could be scaled up for heavy-duty pickup trucks and vans implementation. Light heavy-duty diesel powertrains can also benefit from hybridization and heavy-duty versions of LD efficiency technologies.[83,84,85] Hybrid versions of LD vans and pickups today suggest that mild, strong, or plugin hybridization may be viable options for certain heavy-duty pickup truck and van applications.[86] ICCT commends NHTSA for incorporating many of these technologies into its modeling of the HD pickup and van fleet, and recommends NHTSA adjust costs and effectiveness in a manner similar to that described above for the light-duty versions of the relevant technologies.

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[82] Isenstadt, A., Yang, Z., Searle, S., German, J. (2022). Real World Usage of Plug-in Hybrid Vehicles in the United States. *International Council on Clean Transportation.* https://theicct.org/publication/real-world-phev-us-dec22/

[83] Isenstadt, A., German, J. (2017). Diesel Engines. *International Council on Clean Transportation.* https://theicct.org/publication/diesel-engines/

[84] Buysse, C., Sharpe, B., Delgado, O. (2021). Efficiency technology potential for heavy-duty diesel vehicles in the United States through 2035. *International Council on Clean Transportation*. https://theicct.org/publication/efficiency-technology-potential-for-heavy-duty-diesel-vehicles-in-the-united-states-through-2035/

[85] Posada, F., Isenstadt, A., Badshah, H. (2020). Estimated cost of diesel emission-control technology to meet the future California low NOx standards in 2024 and 2027. *International Council on Clean Transportation.* https://theicct.org/publication/estimated-cost-of-diesel-emissions-control-technology-to-meet-the-future-california-low-nox-standards-in-2024-and-2027/

[86] According to the MY2023 Fuel Economy Guide (https://fueleconomy.gov/feg/download.shtml), the Ford F150 hybrid is 17%-20% more efficient in combined, unadjusted (2-cycle) fuel consumption than its non-hybrid counterpart with the same 3.5L engine; the Pacifica PHEV in charge sustaining mode is 31% more efficient than its equivalent non-hybrid counterpart (3.6L engine); Tundra HEV is 5.3%-10.3% more efficient than non-HEV equipped with Atkinson cycle engine; Ram 1500 mild hybrid is 13.3%-16% more efficient than its non-hybrid version

Just as many LD ICE technology improvements extend to heavy-duty pickup trucks and vans, all of the innovations and developments in BEV technologies and battery packs discussed earlier also apply to both heavy-duty pickup trucks and vans. In a 2022 study on relative costs of EV class 2b/3 vehicles, ICCT projected that pickups and vans of 300-mile range or less would reach price parity with their diesel counterparts within the timeframe of this proposal.[87] Over the first five years of ownership, HD BEVs of 300-mile range or less reach total cost parity with both their diesel and gasoline counterparts before 2030. In other words, well within the timeframe of the proposal battery-electric HD pickups and vans are cheaper to purchase and own than their non-plugin variants.

[87] Mulholland, E. (2022). Cost of electric commercial vans and pickup trucks in the United States through 2040. ICCT. *International Council on Clean Transportation.* https://theicct.org/publication/cost-ev-vans-pickups-us-2040-jan22/