

Meeting the mark:

Aligning regulations and standards with ZEV targets

DALE HALL



The Zero Emission Vehicles Transition Council is an international forum focused on enhancing political cooperation on the transition to zero emission vehicles (ZEVs).

It brings together Ministers that represent over 50% of the global car market. Council members have agreed to collectively address some of the key challenges in the transition to ZEVs, enabling the transition to be faster, cheaper, and easier for all.

The Council will convene on a regular basis to discuss how to accelerate the pace of the global transition to ZEVs, to reduce emissions and help the global economy meet our goals under the Paris Agreement.

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Executive summary

The transition to zero-emission vehicles (ZEVs) is an important component of governments' plans to meet climate goals. An increasing number of governments are announcing timelines to transition new vehicle sales to ZEVs, both in the form of high-level targets as well as binding regulations that will spur more ZEV sales. These timelines can send a clear signal to all stakeholders—manufacturers, fleets, grid operators, and charging infrastructure providers—to plan and coordinate investments, thus enabling an efficient and smooth transition to ZEVs. However, in many of the largest vehicle markets, targets and binding regulations are either lacking entirely or are not aligned in scope and ambition.

This paper catalogues targets for new ZEV sales and supporting regulations and standards—including ZEV sales requirements and performance-based regulations like CO₂ and fuel economy standards—in leading governments and major vehicle markets. The paper examines targets and regulations for light-, medium-, and heavy-duty vehicles in ZEV Transition Council member governments, as well as in Australia, Chile, China, and New Zealand.

The study compares these regulations in terms of their stringency and scale, and identifies which regulations are the most ambitious within each category and vehicle sector. The study also assesses, for each of these governments, whether the binding regulations will require 100% ZEV sales and if they are aligned with non-binding ZEV sales targets.

Table ES1 displays the results of this exercise. For three categories of vehicles—light-duty cars, vans, and trucks; buses; and heavy commercial trucks—the table lists whether the governments considered have binding regulatory frameworks in place, whether these standards are sufficiently strong enough to meet ZEV sales targets, and whether the standards reach 100% ZEV sales (or EV sales, in the case that plug-in hybrids are included).

Table ES1. Governments with standards proposed or in place, their alignment with ZEV targets, and whether they reach 100% ZEV sales

Vehicle segment	Governments with ZEV targets but no standards	Governments with standards in place	Governments with standards matching ambition of ZEV targets	Governments with standards reaching 100% ZEVs
Light-duty vehicles (cars, vans, and light trucks)		Australia, California, Canada, Chile, European Union, India, Japan, Mexico, New Zealand, South Korea, United Kingdom, United States	California, Canada, China, European Union, United Kingdom, United States	California (EVs), Canada (EVs), European Union, <i>United Kingdom</i>
Buses	Chile, <i>Mexico</i> , New Zealand	California, Canada, China, European Union, India, Japan, United States	California, China, European Union	California, European Union
Heavy trucks	Chile, <i>Mexico</i> , New Zealand	California, Canada, China, European Union, India, Japan, United Kingdom, United States	California, China	California

Note: Governments with proposed standards or targets are shown in italics.

This assessment further yields the following conclusions:

Governments have implemented a variety of regulatory approaches, shaped by local conditions, to spur the ZEV transition. Over several decades, leading governments like those in the ZEV Transition Council have implemented pioneering regulations to encourage the adoption of clean vehicle technologies. These regulations—including technology-neutral, performance-based standards and ZEV sales requirements—have been applied to light-, medium-, and heavy-duty vehicles and adapted to local circumstances with carefully calibrated compliance flexibilities. Policymakers have a menu of options and examples to draw upon to develop regulations suitable for any global market to close the gap between ZEV ambition and real market transformation.

Regulations differ greatly in terms of time horizon and level of ambition, with implications for how much they will drive ZEV sales. For light-duty vehicles, the European Union's CO₂ standards and Québec's ZEV regulation are the only policies which will ensure 100% ZEV sales (by 2035). The United Kingdom's ZEV mandate, as well as performance-based standards in Korea and New Zealand, require the swiftest movement toward clean vehicles, but do not extend to 100% ZEV sales. Heavy-duty regulations are less numerous, and California's ZEV sales requirements are by far the strongest supply-side policy. The European Union has proposed a strong framework which will dramatically grow the heavy-duty ZEV market, including reaching 100% ZEV bus sales, and China has near-term standards which will ensure continued growth.

Regulations for light-duty vehicles are more aligned with sales targets than heavy-duty regulations, but gaps remain between ambition and binding regulation for all vehicle types. Three governments covering 17% of global sales—California, Canada, and the European Union—have adopted binding regulations to ensure that 100% of new light-duty vehicle sales in 2035 will be ZEVs (including PHEVs in California and Canada). Three more governments—China, the United Kingdom, and the United States—have regulations in place which will drive the ZEV market toward their goals; together, these regions make up over two thirds of the global new light-duty vehicle market. Nonetheless, some of the world's largest vehicle markets—including several like India and Mexico which have committed to moving to ZEVs—lack regulatory frameworks entirely or have regulations which are insufficiently stringent enough to assist in the ZEV transition. In contrast, only California has adopted binding regulations requiring 100% ZEV sales of medium- and heavy-duty vehicles (buses and trucks). Most other markets, including those which have committed to fully transition heavy-duty vehicle sales to ZEVs, lack binding regulations or have regulations which are not strong enough to ensure their goals are met, calling into question the rigor of these targets and reaffirming the importance of developing strong regulations in additional markets.

Introduction

The transition to zero-emission vehicles (ZEVs) is well under way around the world,¹ made possible by technological innovations and driven by climate and air quality benefits, in addition to lower operating costs. Previous ICCT analysis for the ZEV Transition Council indicated that to keep the road transport sector on a trajectory aligned with keeping global temperature rise under 2 degrees Celsius, consistent with the Paris Agreement, new ZEV sales will have to accelerate, particularly in the largest vehicle markets.² A pathway in which ZEVs account for 100% of new light-duty vehicle sales by 2030–2035 in leading markets, and close to 100% of new sales globally by 2040, would keep the road transport sector aligned with this climate trajectory. Progress on zero-emission trucks would be somewhat slower, accounting for a majority of sales in China and Europe by 2030 and nearly 95% of new sales globally in 2040.

To achieve these milestones and realize the accompanying benefits, governments have a critical role to play in overcoming the barriers of vehicle availability, affordability, and access to charging through targeted policy.³ Among governments' tools to spur the ZEV transition are non-binding targets for ZEV uptake, which can serve as signals to all stakeholders involved in the ZEV transition, and supply-side vehicle regulations, which require improvements in vehicle efficiency or increasing sales of ZEVs. These policy tools are key in enabling a wide variety of stakeholders—including vehicle manufacturers, component suppliers, fleet owners, financiers, electric utilities, and charging infrastructure providers—to plan toward common objectives, which in turn can unlock production efficiencies and economies of scale.⁴

The number of governments with ZEV targets and vehicle performance or sales regulations has grown globally, but many jurisdictions with targets do not have regulations in place, or they are not aligned in time horizon or stringency. When these do not align, ZEV targets may be viewed as less credible by manufacturers, fleet owners, and other stakeholders in the ZEV ecosystem. This could result in higher costs, uneven charging infrastructure deployment, or missing targets altogether.

With this in mind, the ZEV Transition Council committed in its 2023 Action Plan to share best practices on emission standards and regulations for new light- and heavy-duty vehicles.⁵ To support this objective, this paper compares the pace of vehicle electrification required by adopted and proposed regulations in the largest and most advanced ZEV markets, including those which are members of the ZEV Transition Council.⁶ It also investigates whether jurisdictions with ZEV targets have binding regulations in place, and whether those regulations are sufficiently strong enough to keep the market on pace to meet the targets. This assessment is then used to indicate gaps where new or strengthened

1 Unless otherwise noted, ZEVs refer to vehicles with zero tailpipe emissions, including battery electric vehicles (BEVs) and fuel-cell electric vehicles. Electric vehicles (EVs) refer to ZEVs as well as plug-in hybrid electric vehicles (PHEVs), which are included in some governments' ZEV transition plans.

2 Arijit Sen and Joshua Miller, "Vision 2050: Update on the Global Zero-Emission Vehicle Transition in 2023" (International Council on Clean Transportation, 2023), <https://theicct.org/publication/vision-2050-global-zev-update-sept23/>.

3 Dale Hall, Yihao Xie, Ray Minjares, Nic Lutsey, and Drew Kodjak, "Decarbonizing Road Transport by 2050: Effective Policies to Accelerate the Transition to Zero-Emission Vehicles" (ZEV Transition Council, 2021), <https://theicct.org/publication/zevtc-effective-policies-dec2021/>.

4 UK Department for Transport, "Zero Emission Vehicle Mandate and CO₂ Regulations — Joint Government Response Cost Benefit Analysis" (October 2023), https://www.legislation.gov.uk/uksi/2023/1394/pdfs/uksiod_20231394_en_001.pdf.

5 "Action Plan 2023," ZEV Transition Council, accessed March 14, 2024, <https://zevtc.org/action-plan-2023/>.

6 The members of the ZEV Transition Council are California, Canada, Denmark, the European Commission, France, Germany, India, Italy, Japan, Mexico, Netherlands, Norway, Spain, South Korea, Sweden, the United Kingdom, and the United States.

regulations may be needed and to identify opportunities for more governments to lock in progress toward their own ZEV transitions.

Background on zero-emission vehicle targets and regulations

This study compares the ambition and alignment of non-binding ZEV targets or commitments with legally binding regulations and standards that are intended to reduce the greenhouse gas (GHG) emissions from the operation of road vehicles. The governments considered include members of the ZEV Transition Council as well as others which have enacted such policies: Australia, Chile, China, and New Zealand.

Phase-in targets for ZEVs as discussed in this paper are official statements or commitments for a certain share of new vehicle sales to be zero-emission in a particular year; these include 100% targets as well as interim targets. Targets can take the form of legislation, executive orders, and strategies offered by relevant agencies. In some cases, targets may be created as part of a binding regulation, but the targets express an overall goal and do not have an enforcement mechanism. Countries which have signed international agreements on such targets are also included. For example, the Zero Emission Vehicles (ZEV) Declaration includes a commitment for all new cars and vans to be zero-emission globally by 2040, and by no later than 2035 in leading markets.⁷ For medium- and heavy-duty vehicles, signatories of the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles (Global MOU) commit to 100% zero-emission new truck and bus sales by 2040, with an interim goal of 30% zero-emission vehicle sales by 2030.⁸ The targets in the ZEV Declaration and the Global MOU were selected based on the pace of ZEV transition needed to align road transport decarbonization pathways with Paris Agreement objectives.⁹

The study considers two main types of regulations. The first and most common form of regulation is performance-based CO₂ or GHG standards, which set limits on the emissions per kilometer driven, or fuel efficiency standards, which set limits on the amount of fuel consumed per kilometer driven. These standards may either set requirements at a manufacturer average level or as a per-vehicle maximum, and may be adjusted based on vehicle size, weight, engine power, or other criteria. For example, separate limits based on engine power and for categories defined by axle and chassis configuration are generally adopted for medium- and heavy-duty vehicles. For the purpose of this paper, CO₂ or GHG standards and fuel economy standards are considered interchangeable, as vehicle tailpipe greenhouse gas emissions (primarily CO₂) are proportional to fuel consumption.

Fuel efficiency regulations for cars were first adopted by the United States to address energy security in 1975 and have more recently been adopted in most major vehicle markets to meet climate or energy security objectives. Similar measures for medium- and heavy-duty vehicles, first implemented in Japan in 2005, are less common and currently apply in only seven markets, as described later in this report. These regulations are broadly technology-neutral, and can be met through a variety of strategies, including sales of ZEVs, plug-in hybrid vehicles, and more efficient

7 “COP26 Declaration on Accelerating the Transition to 100% Zero Emission Cars and Vans,” Accelerating to Zero Coalition, 2021, <https://acceleratingtozero.org/the-declaration/>.

8 “Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles,” Global Commercial Vehicle Drive to Zero, 2024, <https://globaldrivetozero.org/mou-nations/>.

9 Sen and Miller, “Vision 2050: Update on the Global Zero-Emission Vehicle Transition in 2023.”

combustion-engine vehicles. Despite this flexibility, these policies have helped to drive ZEV sales, and at sufficient stringency, a high fraction of ZEV sales will be necessary for compliance.¹⁰

The second type of regulation considered is ZEV sales requirements, also called ZEV standards or ZEV mandates, which set requirements for the share of new vehicles by each manufacturer which must be zero-emission. In contrast to fuel efficiency or GHG regulations, these regulations must be met primarily by selling more ZEVs as a share of new vehicles rather than by improving the efficiency of combustion-engine vehicles. This provides less compliance flexibility for vehicle manufacturers but offers greater certainty that ZEV targets will be met. In turn, this also provides certainty for other stakeholders supporting the ZEV transition. The first such program took effect in California in 2003 with requirements for light-duty vehicles, and regulations of this type have since been adopted in one other U.S. state and the District of Columbia, China, and the United Kingdom. In Canada, similar regulations have been adopted at the federal level and separately in two provinces. California also has a ZEV sales requirement for medium- and heavy-duty vehicles; this regulation, described later in this paper, has been adopted by 11 other U.S. states.

Light-duty vehicles

Zero-emission vehicle targets and commitments

The light-duty ZEV market, encompassing cars, vans, and light trucks, has grown steadily over the past decade, with ZEVs accounting for about 11% of new sales in 2023 worldwide.¹¹ With growing sales, more vehicle models becoming available, and battery prices falling, an increasing number of governments are setting commitments to transition to ZEVs. Many countries have committed to 100% ZEV sales, with many leading markets targeting 2035 or earlier and a wider variety of markets targeting 2040, including those which have signed the ZEV Declaration. Other markets have set lower targets, such as China, India, and the United States.¹² Some governments have established other types of ZEV goals, like California's goal of 5 million EVs on the road by 2030 and New Zealand's goal of EVs representing 30% of light-duty vehicle stock by 2035; these targets are not assessed further in this paper as they are more challenging to directly compare.

10 Markus Fritz, Patrick Plötz, and Simon A. Funke, "The Impact of Ambitious Fuel Economy Standards on the Market Uptake of Electric Vehicles and Specific CO₂ Emissions," *Energy Policy* 135 (December 1, 2019): 111006, <https://doi.org/10.1016/j.enpol.2019.111006>; Chandan Bhardwaj and Jonn Axsen, "How Stringent Should Vehicle Emission Standards Be? Simulating Impacts on Greenhouse Gas Emissions, Zero-Emissions Vehicle Sales, and Cost-Effectiveness," *Canadian Public Policy*, March 4, 2024, e2023002, <https://doi.org/10.3138/cpp.2023-002>; Nic Lutsey, "Modernizing Vehicle Regulations for Electrification" (International Council on Clean Transportation, 2018), <https://theicct.org/publication/modernizing-vehicle-regulations-for-electrification/>.

11 Ilma Fadhil and Chang Shen, "Electric Vehicles Market Monitor for Light-Duty Vehicles: China, Europe, United States, and India, 2023" (International Council on Clean Transportation, 2024), <https://theicct.org/publication/ev-ldv-major-markets-monitor-2023-may24/>. EV-Volumes, "EV Data Center," 2024, <https://www.ev-volumes.com/datacenter/>.

12 Biden-Harris Administration Announces New Private and Public Sector Investments for Affordable Electric Vehicles," The White House, April 17, 2023, <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/>; "NITI Aayog Convenes India's Electric Mobility Enablers under G20 Presidency," Press Information Bureau, July 20, 2023, <https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1941114>; State Council of People's Republic of China, "Central Committee of the Communist Party of China State Council Opinions on Comprehensively Promoting the Construction of Beautiful China," Official Gazette of the State Council, December 27, 2023, https://www.gov.cn/gongbao/2024/issue_11126/202401/content_6928805.html.

Table 1 summarizes the ZEV targets announced by governments considered in this paper, alongside their actual electric vehicle share of light-duty vehicle sales (including BEVs and PHEVs) in 2023.¹³ Targets labeled as ZEV include only vehicles which are fully zero-emission at the tailpipe, whereas targets labeled as EV may also include plug-in hybrid vehicles. The European Union's goal of 100% ZEV sales in 2035 was created as part of its CO₂ standards, rather than being announced separately, but some EU or European Economic Area members have set earlier goals: Norway aims for 100% ZEV sales by 2025, and Austria, Greece, Iceland, the Netherlands, and Slovenia set goals of 100% ZEV sales by 2030.

Table 1. Light-duty ZEV targets considered in this paper compared to 2023 sales shares

Government	2023 ZEV sales share	ZEV sales share goal										
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Australia	7.5%	No ZEV sales share goal										
California	23%	100% EV in 2035										
Canada	7.1%	100% EV in 2035										
Chile	0.5%	100% EV in 2035										
China	23%	45% EV in 2027 ^a										
Denmark	33%	100% ZEV in 2035 ^{b,c}										
European Union	15%	100% ZEV in 2035 ^b										
France	15%	100% ZEV in 2035										
Germany	18%	100% ZEV in 2035 ^b										
India	1.8%	30% EV in 2030										
Italy	4.1%	100% ZEV in 2035 ^b										
Japan	2.0%	No ZEV sales share goal										
Mexico	1.1%	50% EV in 2030										
Netherlands	28%	100% EV in 2030										
New Zealand	19%	No ZEV sales share goal										
Norway	72%	100% ZEV in 2025										
Spain	5.5%	100% ZEV in 2035										
South Korea	11%	33% EV in 2030										
Sweden	36%	80% EV in 2030										
United Kingdom	15%	100% ZEV in 2035										
United States	7.5%	50% EV in 2030										

Note: The bars and the sales share column are shaded according to the sales share target, with darker green indicating a higher market share.

^a China's goal is for 45% of all new vehicles—light-, medium-, and heavy-duty—to be new energy vehicles (including BEVs, PHEVs, and fuel cell vehicles) by 2027. Because light-duty vehicles comprise the majority of new vehicle sales and are transitioning to EVs faster than heavy-duty vehicles, the target is listed in this table.

^b This goal was created as a part of a binding regulation.

^c Denmark previously had an ambition of adopting a 2030 target and was working toward making it possible for EU Member States to implement national phaseouts earlier than 2035.

13 EV-Volumes, "EV Data Center"; "Statistik over nyregistreringer [Statistics on new registrations]," Mobility Denmark, accessed July 10, 2024, <https://mobility.dk/nyregistreringer/>.

The table illustrates that most major governments have set clear commitments for growing the ZEV market. Among these governments, only Australia and Japan have not set targets, and New Zealand has set a target for EV stock share, but not for sales. Although there has been substantial progress in the electric vehicle market, growth is inconsistent among countries, and sales will need to accelerate in most jurisdictions to meet government targets. However, the required rate of growth differs substantially: Chile will require a steep rate of growth to go from a 1% EV sales share in 2023 to 100% in 2035, whereas China requires only modest growth from a 34% EV sales share in 2023 to 45% in 2027.

Greenhouse gas and fuel efficiency regulations

Performance-based standards, in the form of vehicle efficiency, GHG, or CO₂ regulations, are in widespread use around the world to meet climate objectives, promote energy security, and offer energy savings for drivers. However, these policies differ in the years of vehicle sales covered, the segmentation of the vehicle market, the test cycle used to assess emissions or fuel consumption, and how emission limits are adjusted per manufacturer, among other factors.

Table 2 summarizes key attributes of the policies adopted or under consideration by ZEV Transition Council members and other governments. The years refer to the coverage of vehicle sales under adopted standards as of April 2024. The right-most column, “adjustment,” indicates how targets for individual manufacturers were set; such adjustments are included in all regulations. A manufacturer whose vehicles are, on average, larger (for footprint-based standards) or heavier (for mass-based standards) than the overall new light-duty vehicle fleet would be subject to a less stringent target. This adjustment allows manufacturers to sell a mix of vehicles to suit different consumer needs, although it may also reduce the stringency of the standard if the average vehicle footprint or mass increases.¹⁴ Unless otherwise noted, the regulations apply only to new vehicle sales. The United Kingdom’s standard applies only to cars and light commercial vehicles (LCVs) that are not zero-emission, with baselines set for each manufacturer based on their 2021 performance; the standard serves as a complement to their ZEV mandate schemes.¹⁵

14 Kate S. Whitefoot and Steven J. Skerlos, “Design Incentives to Increase Vehicle Size Created from the U.S. Footprint-Based Fuel Economy Standards,” *Energy Policy* 41 (February 2012): 402-11, <https://doi.org/10.1016/j.enpol.2011.10.062>; Peter Mock, Uwe Tietge, and Jan Dornoff, “Adjusting for Vehicle Mass and Size in European Post-2020 CO₂ Targets for Passenger Cars” (International Council on Clean Transportation, 2018), <https://theicct.org/publication/adjusting-for-vehicle-mass-and-size-in-european-post-2020-co2-targets-for-passenger-cars/>.

15 “Zero Emission Vehicle (ZEV) Mandate Consultation: Summary of Responses and Joint Government Response,” UK Department for Transport, et al., accessed December 28, 2023, <https://www.gov.uk/government/consultations/a-zero-emission-vehicle-zev-mandate-and-co2-emissions-regulation-for-new-cars-and-vans-in-the-uk/outcome/zero-emission-vehicle-zev-mandate-consultation-summary-of-responses-and-joint-government-response>.

Table 2. Summary of light-duty vehicle greenhouse gas and fuel efficiency regulations considered in this study

Jurisdiction	Years <i>(proposed in italics)</i>	Regulation type	Vehicle categories	Test cycle	Adjustment
Australia	2025–2029	CO ₂	Cars, LCVs	NEDC	Curb weight
Canada	2023–2026 ^a	GHG	Cars, light trucks	U.S. combined	Footprint
Chile	2024–2030	FE	Light-duty vehicles (combined)	WLTP	Curb weight
China	2021–2025, 2026–2030 (LCVs)	FE	Cars, LCVs	WLTP	Tare weight
European Union	2021–2035	CO ₂	Cars, LCVs	WLTP	Curb weight
India	2022–2023	FE	Cars	NEDC	Curb weight
Japan	2020–2030	FE	Cars, LCVs	WLTP (3-phase)	Curb weight
Mexico	2025–2027 ^a	GHG	Cars, light trucks	U.S. combined	Footprint
New Zealand	2023–2027 ^b	CO ₂	Cars, LCVs	WLTP (3-phase)	Tare weight
South Korea	2021–2030	GHG	Cars, light trucks	U.S. combined	Curb weight
United Kingdom	2024–2030	GHG	Non-ZEV cars, non-ZEV LCVs	WLTP	None
United States	2023–2032 ^a	GHG, FE	Cars, light trucks	U.S. combined	Footprint

Notes: FE = fuel efficiency, LCV = light commercial vehicles, WLTP = World harmonized light vehicles test procedure (four-phase unless noted), NEDC = New European Driving Cycle

^a Requirements in these regulations are based on model year rather than calendar year

^b Imported used vehicles are also covered by New Zealand's regulation

Figure 1 compares each of these regulations for light-duty vehicles, displaying the standards from 2024, or the date that the first standards will go into effect, to their end dates. The chart shows a weighted average of the standards for passenger cars and LCVs or light trucks based on the 2023 sales mix in that jurisdiction (or 2022 for Mexico and South Korea); this allows a more accurate comparison between markets which are primarily cars, like in Asia and Europe, to those that are primarily light trucks, like in North America. Furthermore, each of these standards has been adjusted to show grams of CO₂ per kilometer (gCO₂/km) according to the four-phase Worldwide Harmonized Light Vehicles Test Procedure cycle.¹⁶

16 "Passenger Vehicle Greenhouse Gas Emissions and Fuel Consumption," International Council on Clean Transportation, accessed November 9, 2023, <https://theicct.org/pv-fuel-economy/>.

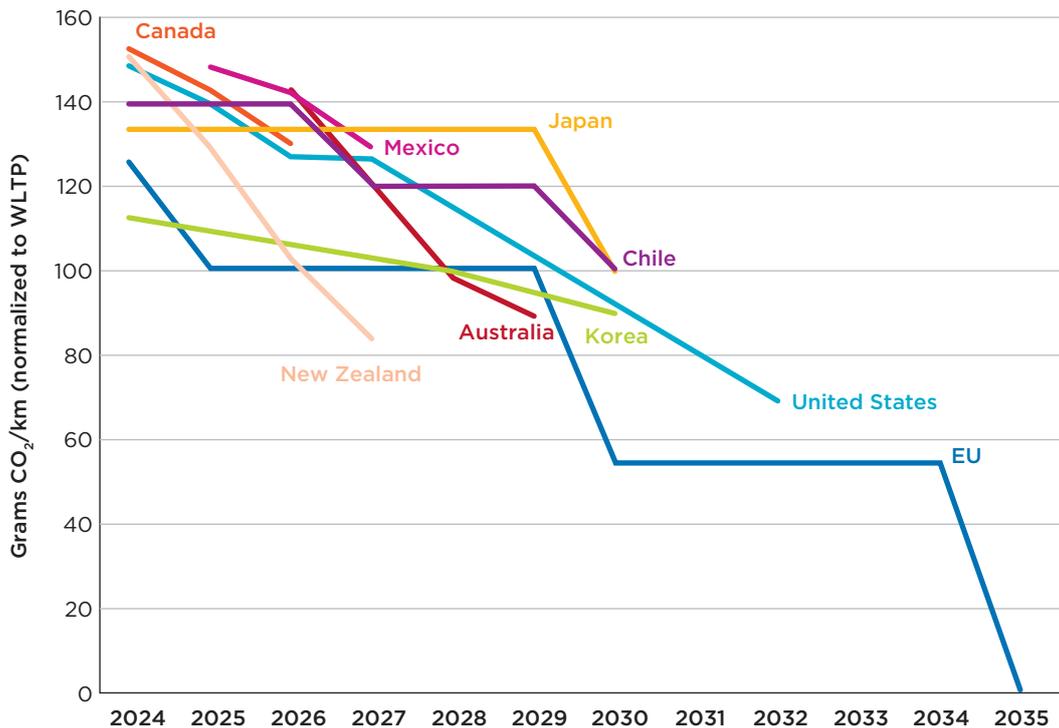


Figure 1. Comparison of light-duty vehicle performance-based standards, 2024–2035. CO₂ values are the sales-weighted average of cars and light commercial vehicles or light trucks

The figure shows that the European Union has the only regulation of this type which reduces to 0 gCO₂/km, effectively requiring 100% ZEVs in 2035. However, some other standards are more stringent than the European Union's in intervening years, in particular South Korea up to 2024, New Zealand in 2027, and Australia in 2028–2029. Standards which require incremental reductions in average emissions each year, such as in New Zealand and the United States, will result in greater emissions reductions over time than standards which increase in stringency at less frequent intervals, like in the European Union and Japan.¹⁷ Standards in Canada, Japan, and Mexico are the least stringent at different points in this time range (prior to 2035).

Flexibilities in performance-based regulations

Although compliance with performance-based regulation is primarily dictated by the average vehicle performance of a manufacturer's sales in a given calendar or model year, most of these regulations contain flexibilities which may or may not affect the pace of emission reductions and number of ZEVs sold. The performance-based standards listed here generally allow some form of trading and banking or carry-forward provisions, enabled by accounting for each manufacturer's performance in units of gCO₂/km or credits representing fuel consumption. Most allow a limited amount of borrowing credits from future years, which could result in delays in ZEV sales. Other notable flexibilities include off-cycle credits and super-credits or multipliers for low- and zero-emission vehicles.

17 Peter Mock, "Europe's Lost Decade: About the Importance of Interim Targets," ICCT Staff Blog (blog), May 9, 2021, <https://theicct.org/europes-lost-decade-about-the-importance-of-interim-targets/>; Transport & Environment, "Cars CO₂ Review: Europe's Chance to Win the Emobility Race" (Transport & Environment, January 2021), <https://www.transportenvironment.org/articles/car-co2-review-europes-chance-win-emobility-race>.

Off-cycle credits are designed to encourage manufacturers to develop and deploy technologies that reduce fuel consumption or greenhouse gas emissions, but which are not reflected under the normal testing procedures.¹⁸ These include technologies like high-efficiency air conditioning, LED lights, and engine start-stop systems. Although these are present in all performance-based regulations listed above, some policies are more expansive than others: For example, in China, only two technologies are eligible, whereas in the United States, 16 technologies are listed as eligible for credits and others may be submitted for approval. The latest regulations in the European Union and United States reduce the maximum contribution of off-cycle credits toward overall compliance, which may favor ZEV sales as a pathway toward compliance.

Multipliers or super-credits provide extra incentive for manufacturers to sell low- or zero-emission vehicles to comply with performance-based standards by weighting these more heavily in the fleet average emissions calculation. For example, in Korea in 2025, each BEV (with emissions counted as 0 g/km) will be weighted by a factor of 2 in the average, whereas each PHEV will be weighted by a factor of 1.5. This has the effect of encouraging manufacturers to sell EVs when they might otherwise not be profitable, but unless the standard is further tightened to account for the multiplier effect, would reduce the emission reductions achieved through the regulation overall.

As of 2024, most markets are phasing out multipliers and they are only available in the United States (ending in 2024), Korea (ending in 2026), and Mexico (ending in 2027). However, the European Union is introducing a zero- and low-emissions vehicle (ZLEV) factor which serves a similar purpose. Under this provision, manufacturers that exceed a zero- and low-emission vehicle sales share of 25% from 2025 to 2029 receive a higher CO₂ target, potentially boosting ZEV sales but reducing overall policy stringency.¹⁹

ZEV sales requirements

In contrast to GHG and fuel efficiency regulations, ZEV sales requirements can only be met through selling zero-emission vehicles, although some jurisdictions also count plug-in hybrid vehicles for compliance. The regulations require manufacturers to earn a certain number of credits (also called values or allowances) each year, which can also be traded among manufacturers. In some cases, credits can be awarded for other actions such as investing in charging infrastructure or reselling secondhand ZEVs. Table 3 summarizes key attributes of four ZEV sales requirements in adopted and proposed policies: the years these requirements are in effect, the categories of vehicles which are given targets, and requirements for BEVs and PHEVs to earn credits under the regulations. New policies take effect in 2024 in China, in 2025 in Québec, and in 2026 in British Columbia and California with different requirements; the credit allocations listed in this table are for the latest phase of policy. Most of these regulations have a single set of targets which apply to all light-duty vehicles (cars, vans, and light trucks); the exception is the United Kingdom, which has separate targets for cars and light commercial vehicles.

While the Canadian federal ZEV sales requirement applies to the entire country, there are additional, more stringent ZEV sales requirements in place in British Columbia and Québec. California's ZEV sales requirement can also be adopted by other U.S. states.

¹⁸ International Council on Clean Transportation, "Passenger Vehicle Greenhouse Gas Emissions and Fuel Consumption."

¹⁹ Jan Dornoff, "CO₂ Emission Standards for New Passenger Cars and Vans in the European Union" (International Council on Clean Transportation, 2023), <https://theicct.org/publication/eu-co2-standards-cars-vans-may23/>.

As of February 2024, eight additional states and the District of Columbia have adopted the regulation through 2035 and three more states have adopted the regulation through 2032;²⁰ together these states comprise 31% of new U.S. light-duty vehicle sales.²¹

Table 3. Summary of light-duty ZEV sales requirements considered in this study

Jurisdiction	Years (proposed in italics)	Vehicle categories	BEV treatment	Plug-in hybrid treatment
California	2017-2035 ^a	Light-duty vehicles	For 2026-2035: 1 credit per BEV with minimum 150-mile range	For 2026-2035: 1 credit per PHEV with ≥ 70-mile range, fractional credits for PHEVs with ranges of 43-70 miles in 2026-2028, with limited contribution to total compliance
British Columbia, Canada	2020-2025, 2026-2035 ^a	Light-duty vehicles	For 2026-2035: 1 credit per BEV	For 2026-2035: 1 credit per PHEV with ≥ 80 km range, with limited contribution to total compliance (PHEVs with ≥ 241 km range are equivalent to BEVs)
Québec, Canada	2018-2035 ^a	Light-duty vehicles	For 2025-2035: 1 credit per BEV	For 2025-2035: 0.5 credits per PHEV with ≥ 80 km range, fractional credits for PHEVs with lower ranges from 2025 to 2027
Canada (national)	2026-2035 ^a	Light-duty vehicles	1 credit per BEV	1 credit per PHEV with ≥ 80 km range, fractional credits for PHEVs with lower ranges from 2026 to 2028, with limited contribution to total compliance
China	2019-2025	Light-duty vehicles	For 2024-2025: 0.95-2.3 credits per BEV according to range	For 2024-2025: 1 credit for PHEVs with minimum 43 km electric range and meeting fuel efficiency criteria; 0.5 credits otherwise
United Kingdom	2024-2030, 2031-2035	Cars, LCVs	1 credit per BEV with minimum 100-mile range	None (credits available for improved non-ZEV efficiency 2024-2026)

Note: LCV = light commercial vehicle

^a Requirements in these regulations are based on model year rather than calendar year

South Korea also has a form of ZEV sales requirement with binding targets from 2023 to 2025; however, because non-ZEVs such as conventional hybrids can earn credits and ZEVs can earn more than one credit, it is not assessed in this comparison.²²

Figure 2 compares the sales requirement trajectories for five of the policies shown in Table 3. Each vehicle may earn multiple credits depending on electric range under existing frameworks in California and British Columbia until 2026, and Québec until 2025, with consequently higher credit requirements. These governments are transitioning to a system which gives one credit per BEV in their new regulations to create greater certainty in ZEV uptake and allow more market flexibility in vehicle range. Those early-year credit requirements are divided by four (the maximum and most common number of credits earned per BEV in each policy) in this figure for consistency. Because each ZEV can earn multiple credits for the duration of the policy in China, its ZEV sales requirements are difficult to compare and therefore are not shown in the figure; however, the policy is likely to drive continued growth in China's ZEV market. The UK trajectory represents a blend of the car and LCV targets according to the 2023 fleet mix (85% cars and 15% LCVs) to more accurately compare with the

20 Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, Washington, and Washington, DC have adopted Advanced Clean Cars II until 2035. Colorado, Delaware, and New Mexico have adopted the regulation until 2032.

21 California Air Resources Board, "States That Have Adopted California's Vehicle Regulations," accessed March 11, 2024, <https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-regulations>.

22 Korea Ministry of Environment, "연간 저공해자동차 및 무공해자동차 보급목표 | 국가법령정보센터 | 행정규칙 [Annual low-emission and zero-emission vehicle distribution goals]," June 18, 2021, <https://www.law.go.kr/admRulLsInfoP.do?admRulSeq=2100000202115>.

other policies, which apply to all light-duty vehicles. A solid line indicates adopted policies, whereas a dashed line is used for the proposed policies in British Columbia and the United Kingdom.

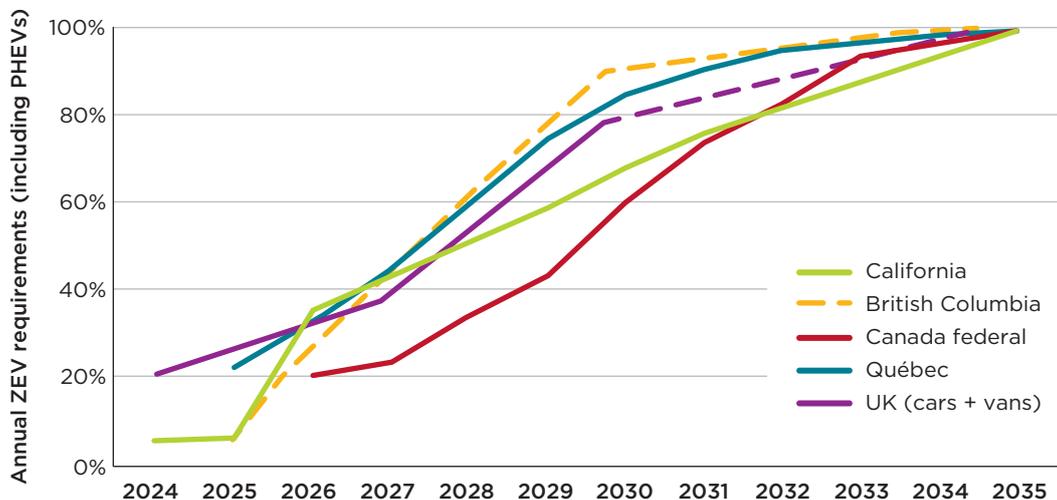


Figure 2. Comparison of ZEV sales requirements, 2024–2035. Dashed lines represent proposed regulations.

As noted in Table 3, these policies vary in their treatment of PHEVs. Figure 2 shows the ZEV credit requirements, including the share which may be accounted for with PHEVs. However, research has shown that PHEVs have higher real-world emissions than previously estimated and higher life-cycle emissions than BEVs. Consequently, these vehicles have been given disproportionate credit for emission reductions under existing test cycles and performance-based regulations.²³ Figure 3 compares the same ZEV sales requirements, but plots the minimum share of ZEVs (excluding PHEVs) which would be required to meet compliance, assuming that manufacturers maximized their compliance via PHEV sales. For the United Kingdom, this includes flexibility in 2024–2026 for a manufacturer to earn ZEV credits by reducing average emissions from non-ZEVs, which can be met through selling more PHEVs.²⁴

23 Patrick Plötz et al., “Real-World Usage of Plug-in Hybrid Vehicles in Europe: A 2022 Update on Fuel Consumption, Electric Driving, and CO₂ Emissions” (International Council on Clean Transportation, 2022), <https://theicct.org/publication/real-world-phev-use-jun22/>; Aaron Isenstadt et al., “Real World Usage of Plug-in Hybrid Vehicles in the United States” (International Council on Clean Transportation, 2022), <https://theicct.org/publication/real-world-phev-us-dec22/>.

24 UK Department for Transport et al., “Zero Emission Vehicle (ZEV) Mandate Consultation.”

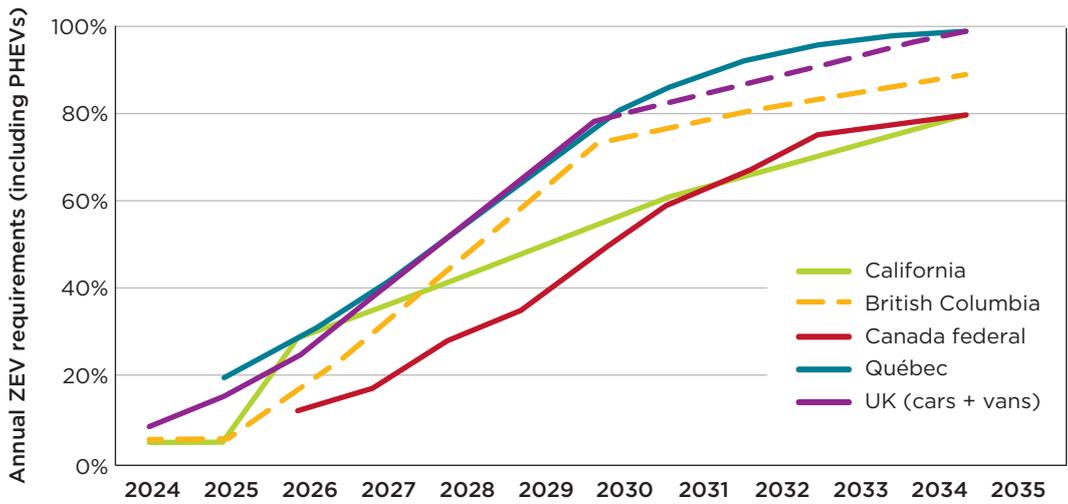


Figure 3. Comparison of ZEV sales requirement requirements, 2024-2035, excluding the share of targets which can be met with PHEVs. Dashed lines represent proposed regulations.

Figures 2 and 3 illustrate that each of these regulations will require considerable increases in the share of ZEVs in the coming decade. The policies in British Columbia and Québec have the highest requirements across most of the 2024-2035 period; if PHEVs are excluded, then Québec and the United Kingdom have the highest requirements. When considering only vehicles which have zero tailpipe emissions, only Québec has a binding policy to require 100% ZEV sales by 2035, aligned with the European Union’s policy discussed above. If adopted, the proposed next stage of the United Kingdom’s regulation would do the same.

Flexibilities in ZEV sales requirements

The ZEV sales requirements compared above are based on the core provisions of each policy and apply to large vehicle manufacturers. All of these programs allow trading of credits among manufacturers and banking of excess credits for use in a later year (carry forward). Some also allow borrowing of credits from future years (carry backward), although this is typically limited through a cap on the number of credits which may be borrowed; in the case of the United Kingdom, there is also a 3.5% annual interest rate on ZEV credits borrowed.

The regulations discussed above include some additional alternative paths to earn ZEV credits. These flexibilities may be intended to minimize the financial impacts on manufacturers, as well as advance other economic, environmental, or social aims. Table 4 lists some examples of compliance flexibilities which may impact ZEV sales in adopted light-duty ZEV sales requirements.

Table 4. Summary of selected flexibilities in light-duty ZEV sales requirements which could impact overall sales

Jurisdiction	Flexibility	Explanation
California	Early compliance credit	ZEVs sold above threshold in model years 2024-2025 may earn credits for use in later years under upcoming more stringent regulations in addition to credits that apply to the current standards.
	Environmental justice credit	Manufacturers may earn credits by selling ZEVs at a discount to community mobility programs in low-income areas (up to 0.5 per vehicle), by selling low-price ZEVs (0.1 per vehicle), or by re-selling a ZEV post-lease in the same state (up to 0.25 per vehicle).
Canada	Infrastructure credits	Manufacturers may earn 1 ZEV credit per \$20,000 invested in new public DC fast charging projects.
United Kingdom	Car club credits	Manufacturers may earn 0.5 extra ZEV credits for ZEVs sold to car clubs (car-sharing fleets).
	CO ₂ trading scheme transfer	From 2024 to 2026, manufacturers selling more efficient non-ZEV vehicles may earn ZEV credits. From 2024 to 2030, manufacturers selling more ZEVs may earn non-ZEV CO ₂ credits.
	Special purpose vehicles	Manufacturers may earn credits by selling zero-emission special purpose vehicles (1.5 credits per zero-emission wheelchair accessible vehicle, and 1 credit per other forms of special purpose vehicles that meet specific criteria).

Each of these alternative opportunities to earn ZEV credits has the potential to reduce the overall number of ZEVs sold. In most cases, these credits are capped, which is an important provision to ensure that compliance flexibilities do not excessively dilute emission reductions and ZEV uptake. For example, early compliance credits in California may account for no more than 15% of a manufacturer's annual requirement, and car club credits in the United Kingdom are limited to 5% of a manufacturer's total vehicle sales in a given year. The impact of flexibilities on the rate of ZEV penetration depends on the design and economics of the specific provision and are challenging to forecast in advance; for this reason, they are not considered in the analysis in this paper.

Alignment of light-duty targets and binding regulations

Table 5 compares policies for light-duty vehicles in the 13 selected vehicle markets in four ways: whether they have an announced ZEV target for new light-duty vehicles, whether they have standards (CO₂, fuel economy, or ZEV) in place as of early 2024, whether the standards are aligned with their ZEV sales goal in terms of the required pace of progress,²⁵ and whether the standards will culminate in 100% of new light-duty vehicle sales being ZEVs. A green box with a "✓" indicates that such criteria is met with fully adopted standards, whereas a yellow box stating "proposed" indicates that such criteria would be met with proposed standards, if adopted. The table also lists the percentage of the global light-duty vehicle market covered by standards within each category, with sales shares calculated based on 2023 light-duty vehicle sales.²⁶

²⁵ Methodology is provided in the appendix.

²⁶ EV-Volumes, "EV Data Center"; "New Car Registrations: +13.9% in 2023; Battery Electric 14.6% Market Share," ACEA - European Automobile Manufacturers' Association (blog), January 18, 2024, <https://www.acea.auto/pc-registrations/new-car-registrations-13-9-in-2023-battery-electric-14-6-market-share/>; "New Commercial Vehicle Registrations: Vans +14.6%, Trucks +16.3%, Buses +19.4% in 2023," ACEA - European Automobile Manufacturers' Association (blog), January 26, 2024, <https://www.acea.auto/cv-registrations/new-commercial-vehicle-registrations-vans-14-6-trucks-16-3-buses-19-4-in-2023/>; Alliance for Auto Innovation, "Advanced Technology Sales Dashboard," 2024, Retrieved March 17, 2024 from <https://www.autosinnovate.org/EVDashboard>

Table 5. Summary of the alignment of light-duty vehicle standards with ZEV targets

Jurisdiction	ZEV goal	Has standards in effect	Standards in line with ZEV goal	Standards adopted to 100% ZEV
Australia		✓	N/A	
California	100% EV by 2035	✓	✓	✓
Canada	100% EV by 2035	✓	✓	✓
Chile	100% EV by 2035	✓		
China	45% EV by 2027	✓	✓	
European Union	100% ZEV by 2035; 5 Member States 100% ZEV by 2030	✓	✓ (except for some member states)	✓
India	30% EV by 2030	✓		
Japan		✓	N/A	
Mexico	50% EV by 2030 (proposed)	✓		
New Zealand		✓	N/A	
South Korea	33% ZEV by 2030	✓		
United Kingdom	100% ZEV by 2035	✓	✓	Proposed
United States	50% EV by 2030	✓	✓	
Percent of global: Adopted	73%	63%		17%
Percent of global: Adopted and proposed	73%	63%		20%

Note: "N/A" for "Standards in line with ZEV goal" indicates that the government does not have a ZEV sales share goal for light-duty vehicles.

In total, all 13 jurisdictions considered have light-duty vehicle standards in effect. However, only half of these markets have fully adopted standards that ensure ZEV targets will be met (with the European Union's standards meeting the ambition of some, but not all, of the Member States). Although South Korea also has standards which will advance the ZEV market, because these extend only to 2025 and have significant flexibilities, they are not counted in this metric.

In total, 73% of the global new light-duty vehicle market is covered by binding standards. The share with regulations aligned with ZEV targets is somewhat lower but still greater than half of the global market (63%). However, only 20% of the global market is subject to standards or proposed standards that extend to 100% ZEVs.

Heavy-duty vehicles

ZEV targets and commitments

The heavy-duty ZEV market is smaller in terms of annual sales volumes compared to light-duty vehicles, with about 51,000 zero-emission buses and 47,000 zero-emission trucks sold in 2023, representing 3% and 1% of the global share of new buses and trucks, respectively.²⁷ The vast majority—over 92%—of cumulative medium- and heavy-duty ZEV sales have been in China.²⁸ However, with zero-emission models rapidly entering the market and becoming cost competitive with internal combustion engine models,²⁹ governments are increasingly setting targets for zero-emission medium- and heavy-duty vehicles. The Global MOU, first launched at COP26 in 2021, has been signed by 33 countries as of the end of 2023, and sets targets for 30% of new medium- and heavy-duty vehicles being ZEVs by 2030 and 100% by 2040.³⁰ The European Commission has adopted a 100% ZEV target only for buses as part of its heavy-duty CO₂ standard, but several countries in Europe have set far-reaching targets either by signing the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles (Austria, Belgium, Croatia, Denmark, Finland, Ireland, Luxembourg, the Netherlands, and Portugal) or with their own targets.³¹

Table 6 summarizes government commitments for sales of zero-emission medium- and heavy-duty vehicles in the same selection of markets shown in Table 3 for light-duty vehicles. In some cases, governments have set targets specifically for urban or transit buses, which have achieved relatively faster ZEV uptake, or for commercial trucks; these are shown in the first two columns. The table also shows the share of new bus and truck sales which were zero-emission in 2023 in these same markets.³² Mexico's targets are part of a draft electromobility strategy due to be finalized in 2024, and as such are not yet official.³³ As noted in Table 1, China has a goal for 45% of all new vehicles—light-, medium-, and heavy-duty—to be new energy vehicles (including BEVs, PHEVs, and fuel cell vehicles) by 2027. Because light-duty vehicles comprise the majority of new vehicle sales and are transitioning to EVs faster than heavy-duty vehicles, the target is not included in this table. Norway has also set a target for 100% of new trucks to be zero-emission or use biogas; because internal combustion engine vehicles fueled with biogas produce emissions at the tailpipe, this target is not listed.

27 "Global EV Data Explorer - Data Tools," International Energy Agency, accessed April 23, 2024, <https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer>.

28 EV-Volumes, "EV Data Center."

29 "ZEV Cost: Total Cost of Ownership," ZEV Transition Council, December 5, 2023, <https://zevtc.org/tracking-progress/zev-cost-total-cost-of-ownership/>; "ZETI (Zero-Emission Technology Inventory)," Global Commercial Vehicle Drive to Zero, 2024, <https://globaldrivetozero.org/tools/zeti/>.

30 Global Commercial Vehicle Drive to Zero, "Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles."

31 "Zero-Emission Vehicle Phase-Ins," International Council on Clean Transportation, accessed April 15, 2024, <https://theicct.org/zev-phase-ins/>.

32 EV-Volumes, "EV Data Center"; "Statistik over nyregistreringer - De Danske Bilimportører."

33 Secretaría de Medio Ambiente y Recursos Naturales, "Estrategia Nacional de Movilidad Eléctrica" (Mexico City, Mexico, June 20, 2023), <https://www.cofemersimir.gob.mx/portales/resumen/55366>.

Table 6. Summary of government commitments for transitioning to heavy-duty zero-emission vehicles and zero-emission sales shares in 2023

Government	Zero-emission transit bus share in 2023	Goal for transit buses <i>(proposed in italics)</i>	Zero-emission commercial truck sales share in 2023	Goal for commercial trucks	Goal for all medium- and heavy-duty vehicles
Australia					
California		100% ZEV in 2029 ^a		100% ZEV in 2036 ^a	
Canada	23%		1.3%		35% ZEV in 2030, 100% ZEV in 2040 ^b
Chile		100% ZEV in 2035			30% ZEV in 2030, 100% ZEV in 2040 ^b
China ^c	50%		2.8%		20% EV in 2026, 22% in 2027, 24% EV in 2028
Denmark	45%	100% ZEV in 2025	6.3%		30% ZEV in 2030, 100% ZEV in 2040 ^b
European Union	15%	100% ZEVs in 2035 ^a	2.3%		
France	13%		6.2%		
Germany	15%		2.3%		
India	6.8%				
Japan	1.1%		<0.1%		
Mexico		<i>50% EV in 2030, 100% EV in 2040, 100% ZEV in 2050^c</i>			50% EV in 2030 ^c
Netherlands	31%	100% ZEV in 2025	5.9%		30% ZEV in 2030, 100% ZEV in 2040 ^b
New Zealand	5.2%	100% in 2025			30% ZEV in 2030, 100% ZEV in 2040 ^b
Norway	53%		11%	50% ZEV in 2030	30% ZEV in 2030, 100% ZEV in 2040 ^b
South Korea	1%				
Spain	13%		1.5%		
Sweden	25%		3.4%		
United Kingdom	17%		2.7%	100% ZEV for trucks ≤ 26 tonnes in 2035; 100% for trucks > 26 tonnes in 2040	30% ZEV in 2030, 100% ZEV in 2040 ^b
United States	1%				30% ZEV in 2030, 100% ZEV in 2040 ^b

^a Goal was created as a part of a binding regulation (performance-based or ZEV sales requirement)

^b Government is a signatory to the Global MOU on Zero-Emission Medium- and Heavy-Duty Vehicles

^c China also has a goal for 45% of all new vehicle sales, light-duty and heavy-duty, to be EV by 2027

^d Targets are part of draft policies which have not yet been finalized

Greenhouse gas and fuel efficiency regulations

Medium- and heavy-duty vehicles include a wide variety of large commercial, passenger, and specialty vehicles which, at a global level, account for around 28% of transport's greenhouse gas emissions. They are also the largest source of health-damaging particulate matter (PM) and nitrogen oxides (NO_x) from transport.³⁴ Performance-based regulations for heavy-duty vehicles are less common and are more varied in their design than for light-duty vehicles. Table 7 summarizes key attributes of heavy-duty GHG and fuel efficiency standards in effect globally. The standards in India do not increase in stringency from 2023 but are still in effect; they are included in Table 7 but not in the following analysis. Because heavy-duty vehicles vary in size and engine power, emission requirements are typically designated for specific vehicle categories. The requirements are then either indexed to vehicle weight and/or body type, as in the European Union and the United States, or set separately for different gross vehicle weight bands, as in China, India, and Japan.

Table 7. Summary of heavy-duty vehicle GHG and fuel efficiency regulations considered in this study

Jurisdiction	Years (<i>proposed in italics</i>)	Regulation type; metric	Vehicles covered
Canada	2018–2027 ^a	Manufacturer average GHG and fuel efficiency; g CO ₂ /ton-mile and gallons/100 miles	Buses and trucks with GVW ≥ 8,500 lbs
China	2019–2021, 2022–2026	Vehicle fuel consumption limit; L/100 km	Vehicles with GVW ≥ 3.5 tonnes
EU	2019–2040	Manufacturer average GHG; g CO ₂ /tonne-km	Rigid and tractor trucks with maximum mass over 16 tonnes, buses
India	2021	Vehicle fuel consumption limit; L/100 km	Diesel vehicles with GVW ≥ 3.5 tonnes
Japan	2019–2025	Manufacturer average fuel efficiency; km/L	Diesel trucks and buses with GVW ≥ 3.5 tonnes
UK	2019–2025	Manufacturer average GHG; g CO ₂ /tonne-km	Rigid and tractor trucks with maximum mass over 16 tonnes
U.S.	2018–2032 ^a	Manufacturer average GHG and fuel efficiency; g CO ₂ /ton-mile and gallons/100 miles Engine CO ₂ emissions and fuel consumption; g CO ₂ /bhp-hour and gallons/100 bhp-hour	Buses and trucks with GVW ≥ 8,500 lbs

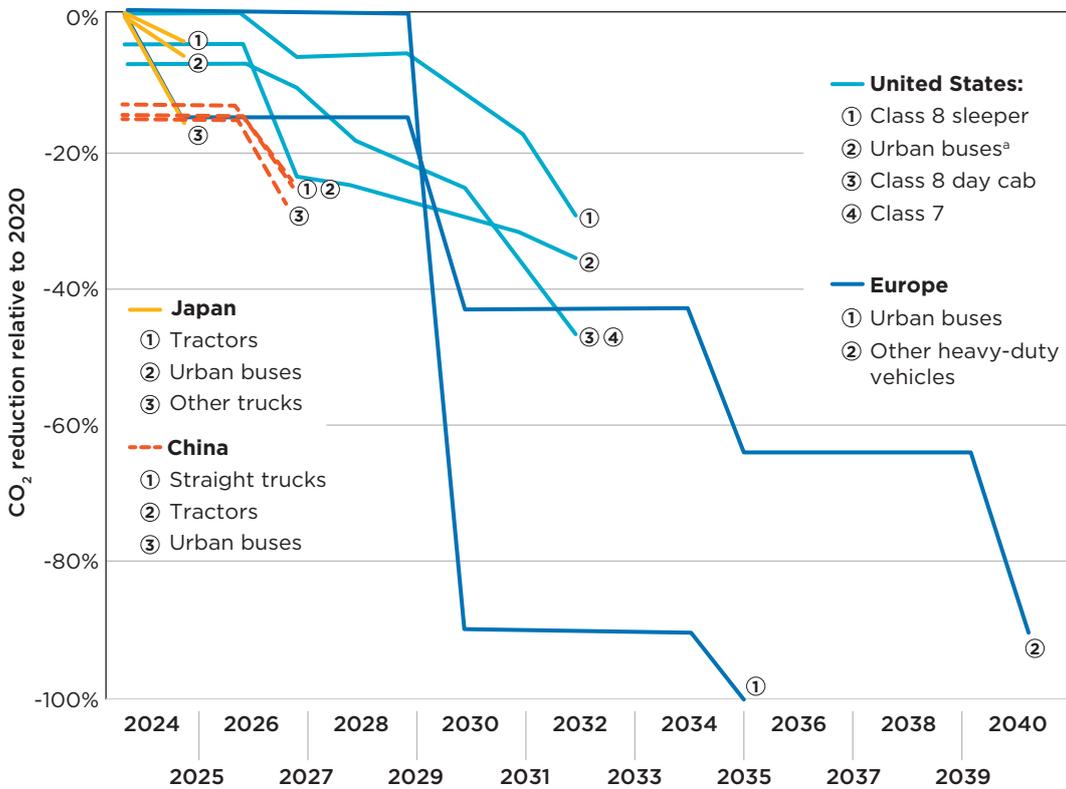
Notes: GVW = Gross vehicle weight, bhp = brake horsepower

^a Requirements in these regulations are based on model year rather than calendar year

Given the differences in test cycles, payloads, and vehicle segmentation, it is challenging to compare these standards directly in terms of CO₂ emission limits. Instead, Figure 4 compares these policies in terms of the required emission reductions from 2020 for regulations in China, the European Union, Japan, and United States,

³⁴ Lingzhi Jin et al., "Air Quality and Health Impacts of Heavy-Duty Vehicles in G20 Economies" (International Council on Clean Transportation, 2021), <https://theicct.org/publication/air-quality-and-health-impacts-of-heavy-duty-vehicles-in-g20-economies/>; Shane McDonagh, "Trucks & Buses," International Energy Agency, accessed April 5, 2024, <https://www.iea.org/energy-system/transport/trucks-and-buses>.

including the proposed regulations in China (indicated with dotted lines).³⁵ For Europe, this is determined from a baselining process based on 2020 registrations for all vehicles which were regulated in existing standards; for China, Japan, and the United States, this is based on the existing regulations in force in 2020 (in Japan, this is unchanged from the 2015 target). For trucks in China and the United States, these lines represent the average of all subcategories, distinguished by weight or roof height, within each segment. Though not shown in this figure, Canada follows the existing U.S. standards until 2027, and the United Kingdom follows the existing EU standards until 2025; both Canada and the United Kingdom are in the process of developing new regulations. Because the adopted regulations in India do not require any additional GHG emission reductions or efficiency improvements after 2021, they are not included in the figure.



^a Represents average of medium-heavy spark- and compression-ignition vocational vehicle requirements

Figure 4. Comparison of improvements required for heavy-duty trucks from 2024 to 2040, relative to 2020 standard or baseline

The figure illustrates that performance-based standards are much less prevalent for heavy-duty trucks compared to passenger vehicles (see Table 3). The European Union generally has the strongest HDV CO₂ standards, which reach a 100% reduction for transit

³⁵ U.S. Environmental Protection Agency, “Final Rule: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3,” Overviews and Factsheets, February 1, 2024, <https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-greenhouse-gas-emissions-standards-heavy-duty>; Benjamin Sharpe, “Second-Phase Fuel Economy Standards for on-Road Heavy-Duty Vehicles in Japan” (International Council on Clean Transportation, 2019), <https://theicct.org/publication/second-phase-fuel-economy-standards-for-on-road-heavy-duty-vehicles-in-japan/>; Shiyue Mao, Liuhanzi Yang, and Yichen Zhang, “The Stage 4 Proposed Amendment to China’s Heavy-Duty Vehicle Fuel Consumption Standard: ICCT Reflections” (International Council on Clean Transportation, 2023), 4, <https://theicct.org/publication/china-hvs-stage-4-amend-reflections-jan23/>; European Commission, “Reducing CO₂ Emissions from Heavy-Duty Vehicles,” 2023, https://climate.ec.europa.eu/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en.

buses in 2030 (effectively requiring 100% ZEVs) and a 90% reduction for trucks and coaches in 2040 relative to 2020. The U.S. standards for Class 7 and Class 8 day cabs are less ambitious than those in the European Union in most years until 2032, the last year covered under the U.S. Phase 3 standards, and the targets for Class 8 sleeper trucks are less ambitious in all years. The U.S. standards require consistent emission reductions for transit buses, which are covered under vocational vehicle standards. These reductions are initially relatively steeper than those in the EU standard but are far surpassed by Europe's requirements starting in 2030. China's Stage 4 proposal will result in approximately 25% less fuel consumption for trucks and 30% less for buses relative to 2020 in 2027, the final year of its standard, outpacing standards in the United States and the European Union. Japan's targets for 2025 require a modest reduction in fuel use from 2015, with no interim targets.

ZEV sales requirements

The Advanced Clean Trucks (ACT) regulation, adopted in 2021 by California and later by several other U.S. states, is the only policy which establishes a ZEV sales requirement for medium- and heavy-duty vehicles.³⁶ ACT sets annual ZEV sales requirements for three categories of trucks from 2024 to 2035: smaller medium-duty trucks (Class 2b-3), medium- and heavy-duty straight trucks (Class 4-8), and tractor trailers.³⁷ Plug-in hybrid trucks, referred to as near-zero emission vehicles in the legislation, may receive partial credits under the regulation. The Advanced Clean Fleets (ACF) regulation, adopted in 2023, builds on ACT and sets a target for 100% of new medium- and heavy-duty vehicles to be zero-emission by 2036.³⁸

The requirements set by these two regulations are depicted in Figure 5 for the three truck segments. The annual percentage requirements for each model year are labeled. The percentage requirements for Class 2b-3 pickup trucks and Class 7-8 tractors are identical for 2024-2032 but diverge for 2033-2035, before both reaching 100% in 2036 under the Advanced Clean Fleets regulation.

³⁶ As of April 2024, ACT has been adopted by Colorado, Maryland, Massachusetts, New Jersey, New Mexico, Oregon, New York, Rhode Island, Vermont, and Washington.

³⁷ California Air Resources Board, "Advanced Clean Trucks Fact Sheet," August 20, 2021, <https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet>.

³⁸ "Advanced Clean Fleets Regulation Summary," California Air Resources Board, April 13, 2023, <https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary>.

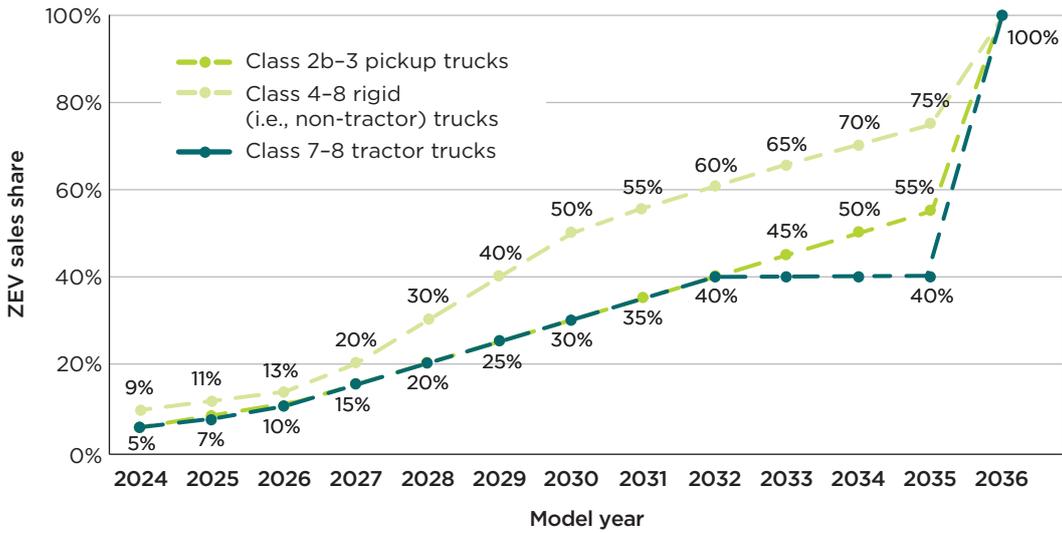


Figure 5. Sales requirements for medium- and heavy-duty trucks under California’s Advanced Clean Trucks and Advanced Clean Fleets regulations, 2024–2036

The ACF regulation imposes additional requirements for in-use fleets which will likely accelerate ZEV sales beyond what is required under ACT. All new drayage trucks registered to enter ports and railyards must be zero-emission from 2024. High-priority public and private fleets must choose to either only purchase ZEVs beginning in 2024 or meet certain targets for the percentage of their medium- and heavy-duty vehicle fleet that must be ZEVs each year. For example, by 2033, 25% of sleeper cabs, 50% of day cabs and work trucks, and 75% of box trucks and vans in a large company’s fleet would have to be zero-emission. The California Air Resources Board estimates that, even before the ACF’s 100% sales requirement goes into effect, the ACF regulation will result in about 190,000 additional medium- and heavy-duty ZEVs being sold in California between 2024 and 2035, beyond the 330,000 sold if only ACT were in place.³⁹

While California’s policies are currently unique in the heavy-duty sector, other governments may follow in implementing ZEV sales requirements. Canada has committed to implementing a medium- and heavy-duty ZEV regulation to meet their 100% target in 2040, with interim targets beginning no later than 2030.⁴⁰ The United Kingdom plans to consult on a new regulatory framework to deliver their commitments for zero-emission heavy-duty vehicles, with a ZEV mandate as one option.

Alignment of heavy-duty targets and binding regulations

Table 8 evaluates which jurisdictions considered in this paper have binding heavy-duty regulations in effect, whether they are in line with their stated ZEV goals,⁴¹ and whether they have formally adopted requirements for 100% ZEV sales. A green box indicates that this criterion is met with standards which are in effect as of early 2024, whereas a yellow box indicates that it would be met if proposed standards were adopted. Unless specified with an icon, the assessment for each cell applies to both buses and trucks. ZEVTC members which are in the European Economic Area (including the European Union) may have different non-binding ZEV commitments, but they are not included as they do not

³⁹ “Advanced Clean Fleets Regulation Summary.”

⁴⁰ Environment and Climate Change Canada, “Canada’s 2030 Emissions Reduction Plan” (Gatineau, Canada, 2022), <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html>.

⁴¹ Details of the methodology are in the appendix.

have the authority to set their own binding standards.

Table 8. Summary of the alignment of heavy-duty vehicle standards with ZEV targets

Jurisdiction	Goal	Has standards in effect in 2023	Standards in line with goal	Standards adopted to 100% ZEV
Australia			N/A	
California	Buses: 100% by 2029 All HDV: 100% by 2036	✓	✓	✓
Canada	All HDV: 35% in 2030, 100% by 2040	✓		
Chile	100% by 2040			
China	All HDV: 20% in 2026, 22% in 2027, 24% by 2028	✓	Proposed	
European Union	Buses: 100% by 2035 Additional ZEV goals in 9 member states	 		
India		✓	N/A	
Japan		✓	N/A	
Mexico	All HDV: 50% EV by 2040, 100% EV by 2050 (draft)			
New Zealand	Buses: 100% in 2025 All HDV: 30% by 2030, 100% by 2040			
South Korea			N/A	
United Kingdom	All HDV: 30% by 2030, 100% by 2040			
United States	All HDV: 30% by 2030, 100% by 2040	✓		

Note: "N/A" for "Standards in line with ZEV goal" indicates that the government does not have a ZEV sales share goal for this vehicle segment. HDV = heavy-duty vehicles

The table shows a mixed picture with a few strong policies alongside notable gaps in regulations to move the heavy-duty vehicle market toward ZEVs globally. California has fully adopted standards which will ensure that 100% of new buses and trucks will be ZEVs. China's proposed standard is likely to drive sufficient ZEV uptake to meet its more modest near-term commitment. In a new regulation adopted in 2024, the European Union established strong, far-reaching standards which will ensure 100% of new buses are zero-emission and dramatically accelerate the zero-emission truck market, although more efforts are needed to meet the 100% ZEV targets of individual Member States. However, several jurisdictions have no regulations in place at all, and some of those with a regulatory framework extend only a few years into the future. Ongoing regulatory processes, such as those in Canada, Chile, India, and the United Kingdom, have the potential to advance the status of heavy-duty regulations and bring the situation more in line with light-duty vehicles.

Conclusions

As the ZEV transition progresses, binding supply-side regulations play a critical role in ensuring that ZEVs are widely available to consumers in volumes sufficient to meet government targets. However, this research illustrates that regulations vary widely among the largest vehicle markets in their approach, time horizon, and stringency, and are not necessarily aligned with a government's stated ZEV commitments. This paper reviews adopted and proposed regulations for light-, medium- and heavy-duty vehicles in both ZEV Transition Council member regions and selected other markets and, where appropriate, compares these regulations to stated ZEV goals. This research yields the following conclusions:

Many governments have binding policies to ensure that light-duty ZEV targets are met, but gaps remain. Three governments covering 17% of global sales—California, Canada, and the European Union—have adopted binding regulations ensuring that 100% of new light-duty vehicle sales in 2035 will be ZEVs (including some PHEVs). Three more governments—China, the United Kingdom, and the United States—have regulations in place which will drive the ZEV market toward their ZEV sales targets. These six regions represent over two thirds of the global new light-duty vehicle market. Nonetheless, some of the world's largest vehicle markets, including several like India and Mexico which have committed to transitioning to ZEVs, lack regulatory frameworks entirely or have regulations which are insufficiently stringent enough to assist in the ZEV transition.

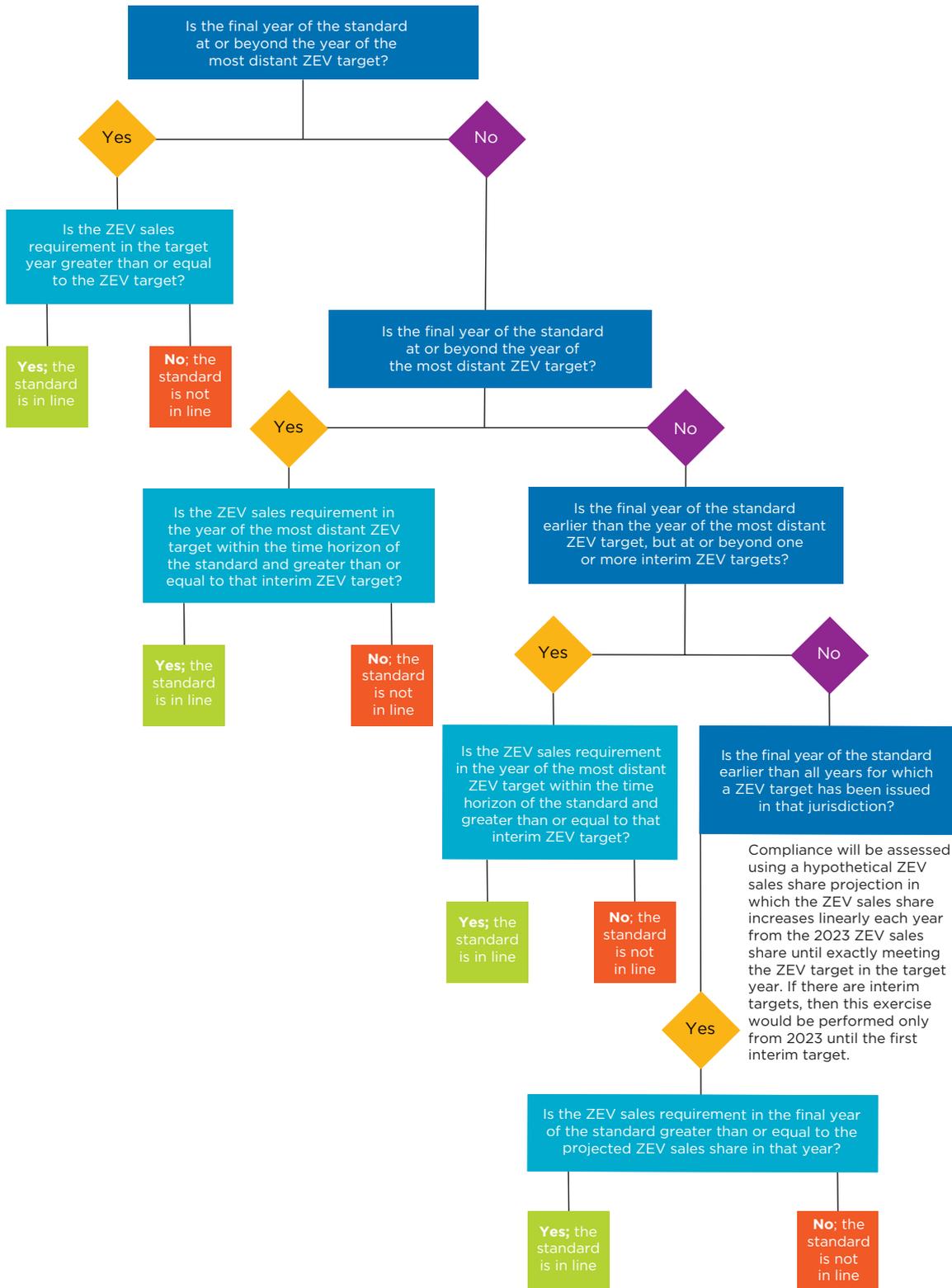
Regulations for heavy-duty vehicles are far less developed than for light-duty, but new regulations under development represent an opportunity for progress. Only one ZEVTC government—California—has adopted binding regulations to require 100% sales of zero-emission medium- and heavy-duty vehicles. The European Union has a strong framework which will grow the heavy-duty ZEV market considerably, including reaching 100% ZEV bus sales, and China has near-term standards which will ensure continued growth. However, most other markets globally, including those which have set goals to fully transition heavy-duty vehicles sales to ZEVs, lack binding regulations entirely or have regulations which are not stringent enough to ensure sales goals are met, calling into question the rigor of these aspirations. Several major markets, including Canada, Chile, India, and the United Kingdom, will have an opportunity to improve the global state of heavy-duty regulations in the coming years.

Governments have implemented a variety of regulatory approaches to spur the ZEV transition based on local conditions. Over several decades, leading governments in the ZEV Transition Council have established pioneering regulations to encourage the adoption of clean vehicle technologies. These include performance-based standards, such as fuel economy, CO₂, or greenhouse gas regulations, which require incremental reductions in the average emissions of new vehicles by selling ZEVs or cleaner conventional vehicles, as well as ZEV sales requirements which stipulate that a certain percentage of new vehicle sales be zero-emission. Both types of regulation have been applied to light-, medium-, and heavy-duty vehicles and adapted to local circumstances with carefully calibrated compliance flexibilities and different vehicle segments. Based on these experiences, policymakers now have a menu of options and strong examples to develop new regulations suitable for any global market to close the gap between ZEV sales ambition and real market transformation.

Appendix: Methodology for assessing whether a standard is in line with a ZEV goal

A: For ZEV sales requirements that have a 1-credit-per-ZEV system:

We assume that ZEV sales requirements are met in-year (i.e., without any banking or borrowing), and that flexibilities offering bonus credits are not used.



B: For performance-based regulations, or ZEV sales requirements that offer multiple credits per ZEV:

Compliance is assessed the same as for ZEV sales requirements with 1 credit per BEV; however, as a first step, annual ZEV sales shares induced by the regulation must be determined. That is done through the following process:

