www.theicct.org

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BRIEFING

APRIL 2019

Overview of global zero-emission vehicle mandate programs

INTRODUCTION

Governments in leading auto markets globally have announced aggressive electrification goals with many targeting a 100% electric share in the 2020–2050 timeframe. These markets are increasingly adopting targeted zero emissions vehicle (ZEV) regulations to accelerate the rate of deployment. Such targeted regulations are in addition to sustained programs and policies supporting consumer incentives, charging infrastructure deployment, and other financial and nonfinancial incentives. For example, California and China have mandates in place that require manufacturers to put more ZEVs on the market, while the European Union has proposed a voluntary target mechanism. These programs are also interlinked with corporate average CO_2 regulations.[1] ZEV mandates alongside stringent CO_2 standards and grid decarbonization provide for an effective policy to achieve game-changing greenhouse gas (GHG) reductions from transport. An earlier ICCT briefing provides an in-depth analysis of how ZEV mandates can accelerate the shift to electric while providing a simpler regulatory framework to drive necessary CO_2 reductions from conventional vehicles.[2]

In addition to the interplay with CO_2 compliance strategies, ZEV mandates also play an important role in overcoming a critical barrier to large-scale electrification. Insufficient model options can deter consumers from purchasing ZEVs even after adequate emphasis on consumer incentives and charging infrastructure. California, which has

1 California's ZEV mandate is also interlinked with exhaust emission standards for automobiles.

2 Nic Lutsey, *Modernizing Vehicle Regulations for Electrification*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/modernizing-regulations-electrification.

Prepared by: Shikha Rokadiya, Zifei Yang

been implementing a ZEV mandate since 1990, has more than 30 ZEV models on the market, in comparison with only a small fraction of that number available in the rest of the United States. California leads the U.S. market in ZEV deployment with a market share more than four times the American average. All automakers subject to California's mandate were compliant with ZEV requirements through 2017, with several manufacturers greatly outperforming the mandates.[3]

Governments in emerging EV markets stand to gain from understanding how mandate programs globally have evolved and their fundamental regulatory design. In this paper we evaluate and compare the ZEV mandate policies in California and nine other states that follow California standards,[4] China, and the voluntary target mechanism in the European Union. These markets collectively account for about 90% of the global ZEV market.

OVERVIEW OF GLOBAL ZEV MANDATE PROGRAMS

The terminology for ZEVs, which are primarily powered by electric drive, varies by region. Electric vehicles are referred to as "new-energy vehicles" (NEVs) in Chinese regulations, as "low-emission vehicles" (LEVs) or "zero low-emission vehicles" (ZLEVs) in EU norms, and as "zero-emission vehicles" (ZEVs) in U.S. regulations. In terms of technologies, most global regulations consider battery operated electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) as pure zero-emission vehicles with higher associated incentives. Other low-emission technologies such as plug-in hybrid electric vehicles (PHEVs) are also counted as ZEVs but with lower associated incentives. We use the term "ZEVs" to broadly refer to all of these vehicles in our review. However, in the context of a specific market being discussed such as China, we use the regional terminology. Further, it is important to note that the global mandate policies reviewed in this paper have been issued only for passenger vehicles, which are the predominant segment in these markets.

CALIFORNIA ZEV MANDATE

ZEV mandates in the United States are implemented at the state level. California has been the pioneer state and first established a ZEV mandate in 1990. Nine other states have adopted California's program. Collectively, these 10 states are referred to as the "ZEV states" and account for more than a third of the total American ZEV market.

REGULATORY PATHWAY

California's 1990 ZEV mandate issued by the California Air Resources Board (CARB) was part of the state's first exhaust standards for automobiles. CARB is part of the California Environmental Protection Agency and regulates emissions of local pollutants and greenhouse gases in California. Since first issued in 1990, the ZEV mandate in

3 "Zero-Emission Vehicle Credit Balances," CARB, accessed March 2019, https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/zero-emission-vehicle-credit-balances.

4 Under Section 177 of the Clean Air Act, other states may adopt California's standards. The nine states that have done so are: Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont.

California has undergone many modifications.[5] In 2012, CARB adopted a broader set of regulations for new cars sold between 2017 and 2025 known as the Advanced Clean Cars (ACC) program.[6] The ACC program includes increasingly stringent ZEV mandates, corporate average GHG standards, and corporate average exhaust emission standards, all working together to reduce emissions from light-duty vehicles.

KEY PROGRAM FEATURES

The ZEV mandate as adopted in the ACC program for model years 2018 to 2025 is reviewed here. Manufacturers classified as "large-volume manufacturers" and "intermediate-volume manufacturers" are subject to fulfilling a certain ZEV percentage credit requirement.[7] The ZEV percentage credit requirement is set to become increasingly stringent and ranges from 4.5% in 2018 to 22% in 2025. Credits are awarded upon the delivery of a ZEV for sale in California. While the percentage credit requirement remains the same for both intermediate and large manufacturers, the two are treated differently in the types of vehicles that can be used to meet the credit requirements. Large-volume manufacturers are required to fulfill a certain percentage of their ZEV credit requirements through pure ZEVs, or BEVs and FCEVs, also known as the "minimum floor volume." Intermediate-volume manufacturers can fulfill their entire ZEV credit requirement through transitional ZEVs (TZEVs), which are predominantly PHEVs that meet certain eligibility criteria as described below.[8] Figure 1 summarizes the total ZEV percentage credit requirement applicable to intermediate- and large-volume manufacturers, including the minimum floor volume applicable to large-volume manufacturers.

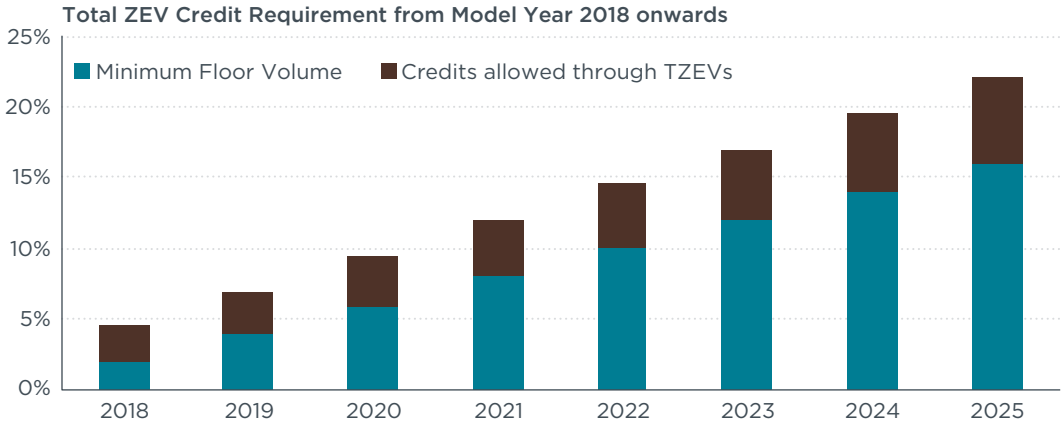

Figure 1. ZEV Percentage Credit Requirements in California's ZEV Mandate Program

The number of credits allocated to a ZEV varies based on the type of ZEV and its all-electric or equivalent all-electric range. Pure ZEVs, or BEVs and FCEVs, can earn a maximum of four credits per vehicle, while TZEVs can earn a maximum of 1.3 credits

5 "Zero-Emission Vehicle Legal and Regulatory Activities and Background," CARB, accessed September 21, 2018, https://www.arb.ca.gov/msprog/zevprog/zevregs/zevregs.htm.

6 "The Advanced Clean Cars Program," CARB, accessed September 21, 2018, https://www.arb.ca.gov/msprog/acc/acc_conceptdraft.htm.

7 See Table 1 for the basis of classification of manufacturers into intermediate- and large-volume categories.

8 PHEV criteria: comply with California's SULEV emission standards, emit zero evaporative emissions, and come with a 15-year/150,000-mile extended emissions warranty and a 10-year/150,000-mile warranty on the energy storage device.

per vehicle. Pure ZEVs with an all-electric range of less than 50 miles and TZEVs with an equivalent all-electric range of less than 10 miles are not eligible for credits. Several pathways are allowed for manufacturers to meet their credit requirements in a given compliance year. For example, manufacturers may bank excess ZEV credits for future use or trade them with other manufacturers. Manufacturers may purchase ZEV credits from other automakers as an alternative to earning them. Further, between 2018 and 2021, eligible manufacturers may offset some of their ZEV credit requirements by over-complying with their corporate average GHG targets. However, if manufacturers fail to demonstrate compliance through all permissible pathways by the next compliance year,[9] they are subject to financial penalties.

Table 1 summarizes the key features of the California ZEV mandate.

Table 1. Summary of Key Program Elements of the California ZEV Mandate

Applicability of ZEV mandate to manufacturers	Manufacturers are classified based on their volume status for each compliance year. Volume status for the compliance year is calculated as the annual average of the manufacturer's sales in California in the previous three years. • Small-volume manufacturers (volume status < 4,500) are exempt from the mandate. • Intermediate-volume manufacturers (volume status > 4,501–20,000 units) are subject to the mandate. • Large-volume manufacturers (volume status > 20,000 units) are subject to the mandate, with a minimum requirement of pure ZEVs • Additional conditions are specified for manufacturers changing status from one category to another across compliance years, including a global revenue test.[a]
ZEV percentage requirement	The California mandate requires manufacturers to meet credit-based requirements, not direct market-share targets. • Affected manufacturers are subject to increasingly stringent ZEV percentage credit requirements between 2018 and 2025, ranging from 4.5% in 2018 to 22% in 2025. • The ZEV percentage credit requirement for a compliance year when applied to the manufacturer's production volume yields the number of credits required for compliance. • Production volume for the compliance year is calculated as the annual average of the manufacturer's sales in California in the prior 2nd, 3rd, and 4th years.[b] • According to CARB, the ZEV mandate program will result in a ZEV market share of about 8% by 2025.[c]

9 Intermediate-volume manufacturers may request a period of up to three consecutive compliance years to make up a deficit.

Types of ZEVs eligible to earn credits	Pure ZEVs (BEVs, FCEVs), transitional ZEVs (PHEVs that meet certain criteria),[d] and a few less-prevalent technology types.[e] • Intermediate-volume manufacturers may fulfill their entire credit requirement through credits earned from transitional ZEVs. • Large-volume manufacturers are obligated to meet a certain percentage of their credit requirement with pure ZEVs, also known as the "minimum floor volume." The minimum floor volume ranges from 2% in 2018 to 16% in 2025.
Credit allocation	Pure ZEVs: • Credits are allocated to pure ZEVs based on their all-electric range (AER).[f] • Vehicles with AER < 50 miles are not eligible to earn any credits while vehicles with AER > 350 miles earn 4 credits per vehicle. • For vehicles with AERs of 50–350 miles, this function is used to determine number of credits earned: 0.01*AER + 0.05. Transitional ZEVs: • Credits are allocated to transitional ZEVs based on their equivalent all-electric range (EAER).[g] • Vehicles with EAER < 10 miles are not eligible to earn any credits while vehicles with EAER > 80 miles earn 1.1 credits per vehicle. • For vehicles with EAER between 10 and 80 miles, this function is used to determine the number of credits earned: 0.01*EAER + 0.3.
Banking, trade, and transfer	• Manufacturers may bank excess credits for future use for 2018 through 2025 compliance. • Manufacturers may trade or sell excess credits to other manufacturers.
Interlinkage of ZEV targets with GHG regulations	• Manufacturers that exceed their corporate average GHG targets between 2018 and 2021 by at least 2 g CO_2/mile may [h] use excess GHG credits to offset ZEV credit requirements up to a specified cap. This cap ranges from as much as 50% of total ZEV credits in 2018 and tightens to as much as 30% of total ZEV credits in 2021. • GHG over-compliance can offset ZEV credit requirements, but excess ZEV credits cannot offset GHG targets.
Penalty	$5,000 per ZEV credit deficit [i]

[a] "Zero-Emission Vehicle Legal and Regulatory Activities and Background," CARB, accessed September 21, 2018, https://www.arb.ca.gov/msprog/zevprog/zevregs/zevregs.htm.

[b] Alternatively, manufacturers can use the compliance year's sales as the production volume, provided it is lower than the prior year's sales by at least 30%. This alternative option can be exercised only twice for compliance between 2018 and 2025.

[c] "ZEV Regulation Factsheet," CARB, accessed September 21, 2018, https://www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf.

[d] PHEV criteria: Comply with California's "super ultra-low emission vehicle" (SULEV) emission standards, emit zero evaporative emissions, and come with a 15-year/150,000-mile extended emissions warranty and a 10-year/150,000-mile warranty on the energy storage device.

[e] In addition to BEVs, FCEVs, and eligible PHEVs, certain other niche technologies are eligible to earn credits including neighborhood electric vehicles and hydrogen electric internal combustion engines.

[f] AER as determined on the U.S. EPA UDDS drive cycle.

[g] EAER as determined on the U.S. EPA UDDS drive cycle. If vehicles demonstrate EAER ≥ 10 miles on the more stringent US06 drive cycle, they earn a flat allowance of 0.2 credit in addition to credits earned based on UDDS EAER.

[h] Manufacturers were required to pre-apply by end of 2016 to use this provision.

[i] Penalty payments do not write off credit deficits, which carry over to subsequent compliance years.

CHINA NEV MANDATE

China's ZEV mandate policy is implemented at a national level and is a modified version of the California ZEV mandate. The ICCT policy update of January 2018 introduced China's mandate policy in detail.[10]

REGULATORY PATHWAY

In 2017, China's Ministry of Industry and Information Technology (MIIT) finalized the New-Energy Vehicle (NEV) mandate policy[11] for passenger cars. NEVs in China refer to those vehicles with new-type power systems, completely or mainly driven by new-energy sources, including PHEVs, BEVs, and FCEVs. The policy specifies mandatory NEV credit targets for manufacturers for 2019 and 2020 with interlinkage to China's corporate average fuel consumption (CAFC) standards. Specifically, excess credits earned under the NEV mandate can be used to offset deficits in CAFC compliance.

KEY PROGRAM FEATURES

The NEV mandate sets annual NEV credit targets at 10% of the conventional passenger vehicle market in 2019 and 12% in 2020. Like California's ZEV mandate, these annual percentage targets are not for NEV sales, but for NEV credits. Each NEV is assigned a specific number of credits ranging from one to six, depending on metrics including electric range, energy efficiency, and rated power of fuel cell systems. These NEV credit targets apply to all auto companies with annual production or import volume of at least 30,000 conventional passenger cars.

Surplus NEV credits can be sold to other companies. Manufacturers unable to meet their NEV targets may offset their deficits through purchased NEV credits. The policy also allows using surplus NEV credits to offset CAFC credit deficits.

Failure to meet NEV credit targets after following all possible compliance pathways will lead to MIIT denial of type approval for new models that cannot meet their specific fuel consumption standards until the deficits are fully offset.

10 Penalty payments do not write off credit deficits, which carry over to subsequent compliance years. https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

11 "Parallel management regulation for corporate average fuel consumption and new energy vehicle credits for passenger cars," MIIT, accessed February 2019, http://www.miit.gov.cn/n1146295/n1146557/n1146624/c5824932/content.html (in Chinese).

Table 2. Summary of Key Program Elements of the China NEV Mandate Policy

Applicability of NEV mandate to manufacturers	Manufacturers with annual production or import of conventional passenger vehicles totaling 30,000 or more are subject to the mandate.
NEV percentage requirement	The China mandate requires manufacturers to meet credit-based requirements, not direct market-share targets. • Affected manufacturers are subject to NEV percentage credit requirements of 10% in 2019 and 12% in 2020. • The NEV percentage credit requirement for a compliance year when applied to the manufacturer's production or import volume of conventional passenger cars in the same year yields the number of credits required. ICCT estimates indicate that the NEV mandate program will result in 2%–10.7% market share for NEVs by 2020.[a]
Types of NEVs eligible to earn credits	BEVs with electric range of at least 100 km, maximum vehicle speed of at least 100 km/h. FCEVs with electric range of at least 300 km. PHEVs with electric range of at least 50 km.
Credit allocation	BEVs: (0.012 x electric range + 0.8) x adjustment factor (0.5, 1, or 1.2[b]), capped at 6 credits per vehicle PHEVs: 2 credits per vehicle x adjustment factor (0.5 or 1[c]) FCEVs (0.16 x fuel cell system rated power) x adjustment factor (0.5 or 1[d]), capped at 5 credits per vehicle
Banking, trade, and transfer	• Manufacturers cannot bank excess credits, except from 2019 to 2020. • Manufacturers cannot carry back negative credits, except from 2020 to 2019. • Manufacturers may trade or sell excess credits to other manufacturers.
Interlinkage of ZEV targets with GHG Regulations	• Manufacturers can use excess self-generated NEV credits or purchase NEV credits to offset a CAFC credit deficit. • GHG over-compliance cannot offset NEV credit requirements.
Penalty	MIIT will deny type approval for new models that cannot meet their specific fuel consumption standards until both CAFC and NEV deficits are fully offset.

[a] The best estimates of the electric range of passenger electric cars lead to ~3 credits per vehicle, which means China's NEV share of new passenger vehicle sales is likely to get to 4% in 2020. Hongyang Cui, *China's new energy vehicle mandate policy*, (ICCT: Washington, DC, 2017), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

[b] Adjustment factor = 1.2 if BEV meets both conditions 1 and 2; adjustment factor = 1 if BEV meets only condition 1; adjustment factor = 0.5 if BEV does not meet neither condition 1 nor 2. Otherwise adjustment factor = 1. Y = energy consumption (kWh/100 km), m = vehicle curb weight (kg). Condition 1: When tested under the electric mode, $Y \le 0.014*m+0.5$ ($m \le 1000$); $Y \le 0.012*m+2.5$ ($1000 < m \le 1600$). $Y \le 0.005*m+13.7$ ($m > 1600$). Condition 2: When tested under the electric mode, $Y \le 0.0098*m+0.35$ ($m \le 1000$); $Y \le 0.0084*m+1.75$ ($1000 < m \le 1600$); $Y \le 0.0035*m+9.59$ ($m > 1600$).

[c] Adjustment factor = 0.5 if PHEV driving range < 80km and PHEV does not meet condition 1 or PHEV driving range ≥ 80km and PHEV does not meet condition 2. Otherwise adjustment factor = 1. Y = energy consumption (kWh/100km), m = vehicle curb weight (kg). Condition 1: When tested under the electric mode, $Y \le 0.014*m+0.5$ ($m \le 1000$); $Y \le 0.012*m+2.5$ ($1000 < m \le 1600$). $Y \le 0.005*m+13.7$ ($m > 1600$). Condition 2: When tested under the nonelectric mode, fuel consumption (L/100 km) is lower than 70% of the current (Phase IV) fuel consumption limits.

[d] Adjustment factor = 1 if the rated power of fuel cell system is no lower than 30% of the rated power of the driving motor or 10kW, whichever is larger. Otherwise, adjustment factor = 0.5.

EU VOLUNTARY ZEV TARGETS

Unlike the markets in California and China, the European Union does not have a true mandate for ZEVs. Instead, the European Union offers manufacturers the option of meeting voluntary ZEV quotas and in return claiming compliance offsets against the proposed post-2021 corporate average standards. The ICCT policy update of January 2019 discusses the proposed post-2021 EU standards in detail.[12]

REGULATORY PATHWAY

The European Commission has specified voluntary ZEV targets as a compliance flexibility mechanism under its post-2021 corporate average CO_2 standards. Manufacturers that exceed these voluntary targets are eligible to receive specified levels of relaxation on their standards. The voluntary ZEV targets and related compliance offsets replace the super credit-based offsets available to manufacturers in the prevailing regulations.

KEY PROGRAM FEATURES

Under the prevailing EU corporate average CO_2 standards, fleetwide emissions from new passenger cars are required to fall to 95 g/km by 2021. For the post-2021 period, the European Commission has proposed to further tighten the standards with a 15% reduction from the 2021 limit by 2025 and a 37.5% reduction by 2030.[13] Manufacturers receive an offset in this target for exceeding specified targets for ZEV market shares in their fleet. These voluntary targets are set at 15% ZEV market share for compliance years 2025–2029, and 35% for 2030.[14] However, not all ZEVs count fully toward these voluntary targets. Vehicles with zero total emissions, or BEVs and FCEVs, get full credit, while those with emissions between 0 g/km and 50 g/km count partially. Vehicles that emit 50 g/km or more are not counted. Assuming a manufacturer achieves 17% BEV sales in 2025, its fleetwide CO_2 compliance target would be relaxed by a factor of 1.02. Similarly, if a manufacturer achieves 39% BEV sales in 2030, its fleetwide compliance target would be relaxed by a factor of 1.04. Manufacturers have an incentive to beat their ZEV targets by as much as 5%, as the CO_2 compliance relaxation factor is capped at a maximum of 1.05. There are no penalties specified in the proposal for manufacturers that miss their ZEV targets.

12 Peter Mock, *CO_2 emission standards for passenger cars and light-commercial vehicles in the European Union*, (ICCT: Washington, DC, 2019), https://www.theicct.org/publications/ldv-co2-stds-eu-2030-update-jan2019.

13 Jonathan Stearns, "Carmakers get a roadmap for tougher EU limits on Carbon Dioxide," *Bloomberg*, December 17, 2018, https://www.bloomberg.com/news/articles/2018-12-17/carmakers-get-road-map-for-tougher-eu-limits-on-carbon-dioxide.

14 Peter Mock, *CO_2 emission standards for passenger cars and light-commercial vehicles in the European Union*, (ICCT: Washington, DC, 2019), https://www.theicct.org/publications/ldv-co2-stds-eu-2030-update-jan2019.

Table 3. Summary of Key Program Elements of ZEV-related Provisions in EU Post-2021 Proposal

Applicability of ZEV target to manufacturers	The ZEV market share targets in the EU post-2021 proposal are voluntary and nonbinding. No applicability criteria are specified for manufacturers to be subject to the target, so all manufacturers can choose to meet the targets and earn a compliance relaxation on annual corporate average emission limits.
ZEV percentage requirements	EU post-2021 proposal specifies voluntary ZEV market share targets for manufacturers: • 2025–2029: 15% share of new vehicle sales. • 2030: 35% share of new vehicle sales. However, not all vehicles fully count toward targets. Vehicles with zero emissions get full credit while others count for partial credit in proportion to emission levels.
Types of ZEVs eligible	All vehicles with tank-to-wheel CO_2 emission value of 50 g/km or lower.
Credit allocation	ZEVs with lower tank-to-wheel CO_2 values count more towards the market share targets. • BEVs and FCEVs are treated as zero-emission vehicles and get full credit. • Vehicles with CO_2 emissions between 0 g/km and 50 g/km count in proportion to their tailpipe emission values according to this function: 1 – [CO_2 Value]/50. • Vehicles with tailpipe CO_2 emissions higher than 50 g/km do not count toward the target.
Banking, trade, and transfer	No provisions specified.
Interlinkage of ZEV targets with GHG regulations	• Manufacturers that beat their ZEV market share targets can receive a proportional relaxation in their corporate average GHG target, up to 5%. For example, if a manufacturer achieves a ZEV market share of 17% in 2025, its corporate average GHG target would be eased by a factor of 1.02. • Overcompliance with ZEV market shares can offset GHG targets, but GHG over-compliance cannot offset ZEV targets.
Penalty	No penalty provisions are specified. The proposed market share targets are voluntary and nonbinding.

COMPARISON OF CALIFORNIA, CHINA, AND EU PROGRAMS

Key design elements of the California and China ZEV mandate programs as well as the EU voluntary ZEV targets in the post-2021 proposal are compared here.

PROJECTED MARKET SHARES:

The percentage mandates specified in the California and China ZEV regulations are based on credit requirements rather than sales targets. Estimates from CARB indicate that the California mandate will result in ZEVs accounting for about 8% of new

passenger vehicle sales in the state by 2025.[15] ICCT estimates indicate that the China mandate will result in ZEVs constituting 4% of new passenger vehicle sales in China by 2020.[16] In contrast, the EU ZEV targets of 15% by 2025 and 35% by 2030 are on a market-share basis.[17] While the California and China targets are true mandates, the EU goals are voluntary. Top-selling ZEV manufacturers in Europe such as BMW, Renault-Nissan, and Mercedes-Benz have all indicated ZEV sales targets that are already at or above the proposed target levels in the standard.[18] In the absence of penalty provisions for missing ZEV targets, it is difficult to estimate whether the EU sales targets will expand Europe's ZEV market.

APPLICABILITY TO MANUFACTURERS:

Manufacturers classified as *small-volume manufacturers* in the California and China ZEV mandates are exempt from meeting ZEV credit requirements. The California system considers manufacturers that sell fewer than 4,500 vehicles annually[19] in the state as small volume. The China system considers manufacturers that produce or import fewer than 30,000 vehicles a year as small volume.

The California system goes one step further and classifies all manufacturers affected by the ZEV mandate as intermediate- or large-volume manufacturers. Intermediate-volume manufacturers are given certain compliance flexibilities compared with large-volume manufacturers. The key flexibility for intermediate-volume manufacturers is that they are not subject to minimum floor requirements, or mandatory quotas for pure ZEVs. The Chinese mandate treats all affected manufacturers at par and does not specify any minimum floor requirements.

Since the proposed ZEV targets in the European Union are integrated into the post-2021 CO_2 compliance standards, all manufacturers subject to the GHG standards are covered under the ZEV targets. However, this aspect becomes moot given that there are no penalty provisions in the EU proposal for missing the ZEV targets.

ELIGIBLE ZEVS AND CREDIT-ALLOCATION SYSTEM:

Table 3 provides a quick summary comparing the eligibility criteria as well as basis of credit allocation[20] within the ZEV target mechanisms in California, China, and the European Union.

15 "ZEV Regulation Fact-Sheet," CARB, accessed September 21, 2018, https://www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf.

16 Hongyang Cui, *China's New Energy Vehicle Policy (final rule)*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

17 However, only pure ZEV technologies such as BEVs and FCEVs count fully toward such market shares, while other technologies such as PHEVs count partially based on tailpipe emissions.

18 The International Council on Clean Transportation, "European Vehicle Market Statistics, Pocketbook 2017/2018." http://eupocketbook.org/.

19 Based on previous three year average sales.

20 For the ZEV credit allocation functions, refer to Table 1 (California), Table 2 (China), and Table 3 (EU) in this paper.

Table 4. Comparison of Eligibility Criteria and Basis of Credit Allocation in California, China, and the European Union for ZEVs

	BEVs	FCEVs	PHEVs
California	*Eligibility:* e-range > 50 miles (80.5 km) *Credits:* Function of e-range	*Eligibility:* e-range > 50 miles (80.5 km) *Credits:* Function of e-range	*Eligibility:* e-range > 10 miles (16.1 km) 15-yr extended emissions warranty[a] 10-yr energy storage device warranty[b] Compliant with SULEV[c] emission standards Zero evaporative emissions. *Credits:* Function of e-range
China[d]	*Eligibility:* e-range ≥ 100 km min. speed ≥ 100 km/h *Credits:* Function of e-range, vehicle curb weight, and electrical energy consumption	*Eligibility:* e-range ≥ 300 km *Credits:* Function of e-range, rated power of fuel cell system, and rated power of driving motor	*Eligibility:* e-range ≥ 50 km *Credits:* Function of e-range, vehicle curb weight, fuel consumption, and electrical energy consumption
EU	*Eligibility:* All BEVs qualify *Credits:* All BEVs treated equally (full vehicle).	*Eligibility:* All FCEVs qualify *Credits:* All FCEVs treated equally (full vehicle).	*Eligibility:* Tank-to-wheel CO_2 emissions[e] of 50 g/km or less *Credits:* Function of tank-to-wheel CO_2 emissions

[a] 15 years or 150,000 miles whichever comes earlier.
[b] 10 years or 150,000 miles whichever comes earlier.
[c] Super Ultra-Low Emission Vehicles, or SULEVs, are vehicles that emit 90% fewer emissions than average gasoline vehicles.
[d] For a detailed flow chart on determining eligibility and credit allocation in China's policy, refer to Figure 2 in: Hongyang Cui, *China's New Energy Vehicle Policy (final rule)*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.
[e] Emissions due to electric operation of the PHEV are considered as zero under EU regulations.

As can be seen from Table 4, the three regions differ in their approach for assessing ZEVs. For BEVs and FCEVs, the California system bases credit allocation entirely on e-range[21] and at slightly lower allowable thresholds compared with China. The China system is more discerning and factors in e-range as well as efficiency-related parameters. In contrast, the European Union would treat all BEVs and FCEVs equally under its proposal regardless of e-range and efficiency.

The California credit allocation system for PHEVs is also based entirely on e-range and at a threshold that is significantly lower than in China. For perspective, the Toyota

21 Earlier versions of the California ZEV mandate included criteria based on fast charging capability in addition to e-range which have been discontinued from 2018 onward.

Prius Prime, the top-selling PHEV in the United States[22] and the second-highest selling in California,[23] has an e-range of 25 mi (40 km).[24] However, the California system requires PHEVs to meet stringent exhaust emission standards and come with specified warranties on the installed emission control and battery systems that are absent in China. The Chinese credit allocation system, on the other hand, factors in efficiency parameters that are absent from the California mechanism.

The EU CO_2 standards consider all vehicles with emissions of 50 g/km or less as ZEVs. In the prevailing standards, all ZEVs with CO_2 emissions of less than 50 g/km are treated equally with respect to the level of incentives provided to manufacturers. This has resulted in an influx of relatively low-range and heavier PHEVs to the EU market. For perspective, about a third of new ZEV sales in 2016 in the European Union were PHEVs with CO_2 emissions near the upper end of the 50 g/km threshold, including top-selling vehicles such as the Mitsubishi Outlander PHEV and Volvo XC90 T8.[25] The proposed post-2021 standards rectify this flaw by awarding market share credits to vehicles as a linear function to the reduction in CO_2 emissions. Thus, BEVs receive full market share credit with zero total emissions, while PHEVs receive partial market share credit based on their tailpipe emissions. Unlike California and China, the ZEV targets in the post-2021 EU CO_2 proposal do not specify eligibility criteria for PHEVs based on e-range.

SURPLUS CREDIT PROVISIONS:

It is important to understand how different policies treat manufacturers that beat their ZEV targets. Such provisions, especially any interlinkage with corporate average CO_2 compliance, can have potentially negative impacts on the efficiency levels of conventional vehicles. We briefly examine here how the ZEV policies differ on aspects concerning credit banking, trade, and transfer, as well as interplay with CO_2 compliance.

1. *Banking, trade, and transfer:* The California system allows banking of ZEV credits for future use through the 2018–2025 period. In China, credits can be carried forward only from 2019 to the 2020 compliance year. Both California and China allow financial trade and transfer of credits between manufacturers. The EU proposal, on the other hand, does not specify any banking, trade, or transfer provisions for companies that exceed ZEV targets. Banking, trade, and transfer provisions could be a useful policy measure to allow manufacturers some flexibility in planning costs to meet their ZEV targets. However, the use of such a flexibility mechanism is warranted provided targets become increasingly and sufficiently stringent over time.

2. *Interplay with CO_2 standards:* The proposed EU and China policies provide GHG compliance flexibility for manufacturers that over-achieve their ZEV targets. For example, if a manufacturer in Europe beats its ZEV target for 2025 by 3%, its GHG

22 "Top 5 selling plug-in electric cars," *Insideevs*, accessed November 2018, https://insideevs.com/top-5-selling-plug-in-electric-cars-march-2018-edition/.

23 Nic Lutsey, *California's continued electric vehicle market development*, (ICCT: Washington, DC, 2018), https://www.theicct.org/sites/default/files/publications/CA-cityEV-Briefing-20180507.pdf.

24 Fuel economy data, U.S. Department of Energy, accessed November 2018, https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=38531.

25 Jan Dornoff, Joshua Miller, Peter Mock, Uwe Tietge, *The European Commission regulatory proposal for post-2020 CO_2 targets for cars and vans*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/ec-proposal-post-2020-co2-targets-briefing-20180109.

compliance standard would be raised by a factor of 1.03. This adjustment is limited to a value of 1.05, so manufacturers have no incentive to exceed their ZEV targets by more than 5%. In China, excess ZEV credits can be used to offset deficits in CAFC credits with no upper limit. In contrast to EU and China, California's policy does not allow offsetting of GHG targets through excess ZEV credits. Rather, it allows the opposite to eligible manufacturers who may offset ZEV credit requirements through excess GHG credits[26].

Integrating ZEVs as a compliance flexibility in meeting GHG standards is not a very effective means of rapidly making the transition to ZEVs and is at best reserved for reaching ZEV market shares of as much as 5%[27] This approach can negatively affect emission levels from conventional vehicles, and the losses can be significant depending on the stringency of the GHG standard, ZEV market share, and carbon intensity of the electric grid. This issue is compounded in the European Union and China as both already have incentives for ZEVs in their GHG regulations that dilute the intended CO_2 benefits of the policies. These incentives are in the form of super-credit multipliers and preferential emissions accounting for ZEVs. While the European Union eliminates super-credit provisions after 2023 and caps the relaxation of the GHG standard at a maximum value of 5% in its post-2021 proposal, it continues to deploy zero-emission accounting. For perspective, BMW and Renault-Nissan, the two top ZEV manufacturers in Europe, can receive reductions of as much as 2 g/km toward their targets for 2021 because of the super credits and zero-emission incentives.[28] Both manufacturers have announced strategies that are already at or well above the proposed target levels in the EU proposal. The dual-credit provision of allowing surplus ZEV credits to offset GHG compliance will only further amplify the allowable erosion in emission levels from conventional vehicles because of the artificial ZEV incentives.[29],[30] Although China differs from Europe as its ZEV targets are binding on manufacturers, it has a comparatively higher grid CO_2 intensity and generous super-credits and zero-emission accounting. In such a scenario, such ZEV incentives can negatively affect China's 2020 fuel consumption standards by as much as 35%.[31]

In comparison with the EU and Chinese ZEV policies, the California mandate does not allow for erosion in conventional vehicle emissions to encourage ZEVs. California's corporate average GHG standards do not provide for super credits or preferential accounting methods for ZEVs. Further, California allows pre-qualified manufacturers to offset their ZEV credit quotas through excess credits earned from both GHG and criteria pollutant compliance between 2018 and 2021. This provision is available

---

26 Manufacturers that exceed their corporate average GHG targets between 2018 and 2021 by at least 2 g CO2/mile may use excess GHG credits to offset ZEV credit requirements up to a specified cap. This cap ranges from as much as 50% of total ZEV credits in 2018 and tightens to as much as 30% of total ZEV credits in 2021.

27 Nic Lutsey, *Modernizing vehicle regulations for electrification*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/modernizing-regulations-electrification.

28 Uwe Tietge, *CO_2 emissions from new passenger cars in the EU: Car manufacturers' performance in 2017*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/co2-emissions-new-passenger-cars-eu-car-manufacturers-performance-2017.

29 Peter Mock, Nic Lutsey, Uwe Tietge, "Off the hook: Europe's current ZLEV proposal would allow CO_2 emissions of new combustion vehicles to increase," *International Council on Clean Transportation Staff Blog*, June 21, 2018, https://www.theicct.org/blog/staff/eu-zlev-proposal-allow-co2-emissions-new-combustion-engine.

30 Hongyang Cui, *China's New Energy Vehicle Mandate Policy (final rule)*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

31 See Table 2 in Nic Lutsey, *Modernizing vehicle regulations for electrification*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/modernizing-regulations-electrification.

provided manufacturers exceed their GHG compliance targets by at least 2 g/mi (about 1.24 g/km) during these years. For perspective, the ACC regulations aim at reducing fleet average exhaust emission levels to SULEV30[32] or lower levels and reducing CO_2 emissions by 34% compared with 2016 levels by 2025.[33] The mandatory ZEV quotas prescribed are a part of this overall emission-reduction strategy. However, with the over-compliance offsets, manufacturers have the flexibility to achieve these emission reductions through improvements in conventional vehicle technology as well in the initial years. While it may be early to comment on the effectiveness of California's approach, such interplay can help reward efficiency improvements in conventional vehicles instead of delaying them as the ZEV markets continue to ramp up. So far, one large-volume manufacturer is expected to avail itself of flexibilities with its ZEV quota during 2018–2021 through over-compliance with its GHG targets.[34]

CREDIT DEFICIT PENALTY PROVISIONS:

California specifies a fixed financial penalty on manufacturers of $5,000 per credit deficit for missing their ZEV credit requirements through all allowable pathways. No manufacturer has had to face the ZEV penalty provision through 2017 in California.[35] China follows a different approach. Instead of financial penalties, China denies market entry of the most polluting models in a manufacturer's fleet until both corporate average fuel consumption standards and ZEV quotas can be met through all allowable pathways. The China ZEV mandate is in its first year of implementation.

The EU post-2020 proposal does not specify any penalty provisions for manufacturers that fall short of their ZEV targets. In the absence of penalty provisions, the proposed EU ZEV target mechanism is effectively the equivalent of a modified super-credit incentive. Estimates from the ICCT indicate this maximum equivalent super-credit value to be 1.25 in 2025–2029 and 1.14 in 2030.

CONCLUDING REMARKS

Governments are increasingly realizing the effectiveness of ZEV mandates in accelerating the market shift to electric. In addition to the market examples summarized in this paper, Colorado has published a proposal for adopting California's ZEV mandate. British Columbia[36] has introduced the Zero-Emission Vehicles Act.[37] Québec has adopted a ZEV mandate program that mostly dovetails with the California

32 Super ultra-low emissions vehicle exhaust standards as per LEVIII exhaust standards. See https://www.transportpolicy.net/standard/california-light-duty-emissions/ for emission standard levels.

33 "Advanced Clean Cars Program Summary," CARB, accessed November 16, 2018, https://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf.

34 Based on feedback from CARB requested by ICCT for this project: Krista Eley, Advanced Clean Cars Branch, e-mail message to Shikha Rokadiya, November 15, 2018.

35 "2017 Zero Emission Vehicle Credits," CARB, accessed November 16, 2018, https://www.arb.ca.gov/msprog/zevprog/zevcredits/2017zevcredits.pdf.

36 "Zero Emission Vehicle Mandate Proposal," Colorado Department of Public Health and Environment, accessed February 2019, https://www.colorado.gov/pacific/cdphe/zero-emission-vehicle-mandate-proposal.

37 "Bill 28-2019 Zero-Emission Vehicles Act," Legislative Assembly of British Columbia, accessed April 2019, https://www.leg.bc.ca/parliamentary-business/legislation-debates-proceedings/41st-parliament/4th-session/bills/first-reading/gov28-1

system.[38] China is considering a ZEV mandate mechanism for light commercial vehicles in addition to the next phase of policy targets for its passenger-vehicle ZEV mandates.[39]

For governments in other markets to consider adoption of ZEV mandates, the first step will be to study the feasibility of such policy formulation, especially the existence of enabling legislation or regulations. Understanding key program elements and implementation experiences of global ZEV mandate policies can then guide program design to be appropriate and contextual for the specific market.

The ZEV programs reviewed in this paper exclusively focus on passenger vehicles and their interplay with fuel economy regulations. There are a variety of other programs that can achieve similar goals as a mandate for manufacturers. Such programs can be aligned with different regulatory pathways and focus on different vehicle modes. For example, caps on conventionally powered vehicles while treating ZEVs preferentially can address air pollution as well as congestion. Beijing caps registration of conventional vehicles[40]; Taipei will ban all conventionally powered motorcycles by 2035[41]; and Paris will ban all conventional vehicles by 2030.[42] In addition to interventions in conventional vehicle registration, ZEVs can also be preferentially promoted through regulated emission zones. London has implemented two zero-emission zones prohibiting gasoline and diesel vehicles during peak traffic hours while allowing access to ZEVs at all times.[43] Although the framing of such programs is not through a ZEV mandate on manufacturers, they can have an equally powerful effect in pushing the uptake of ZEVs. Moreover, such programs can be tailored to accelerate the market shift to ZEVs across segments including passenger cars, two-wheelers, three-wheelers, vocational trucks, urban vehicles, and other commercial vehicles. Some of these programs will effectively function as a 100% ZEV mandate for a certain vehicle segment. While we have not addressed such programs here, they warrant equal consideration alongside the ZEV mandate programs for manufacturers discussed in this paper.

38 The differences include the ZEV target for 2018, the maximum credits per vehicle for low-emission vehicles, minimum floor requirement for large-volume manufacturers, bonus credits, etc. Source: "Québec leads the way with its ZEV standard (2018)", The Climate Group, accessed February 2019, https://www.theclimategroup.org/news/qu-bec-leads-way-its-zero-emission-vehicle-standard.

39 "The Equipment Industry Division organized a seminar on the points management system for energy-saving and new energy commercial vehicles," MIIT, accessed February 2019, http://www.miit.gov.cn/n1146290/n1146402/n1146440/c6025830/content.html (in Chinese).

40 Keju Wang, "Beijing limits new car plates, boosts new energy vehicles," *China Daily*, December 15, 2017, http://www.chinadaily.com.cn/a/201712/15/WS5a33819aa3108bc8c6734ecb.html.

41 "Taiwan to outlaw fuel-powered bukes and cars," *electrive.com*, February 7, 2019, https://www.electrive.com/2018/01/08/taiwan-outlaw-fuel-powered-bikes-cars/.

42 Brian Love, "Paris plans to banish all but electric cars by 2030," *Reuters*, October 12, 2017, https://www.reuters.com/article/us-france-paris-autos/paris-plans-to-banish-all-but-electric-cars-by-2030-idUSKBN1CH0SI.

43 "Urban Access Regulations in Europe," www.urbanaccessregulations.eu, accessed November 19, 2018, http://urbanaccessregulations.eu/countries-mainmenu-147/united-kingdom-mainmenu-205/london.