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ZEV TRANSITION COUNCIL

Decarbonizing road transport by 2050

Accelerating the global transition to zero-emission vehicles

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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

Cars, vans, buses, and trucks account for 21% of global anthropogenic CO_2 emissions. Under currently adopted policies, fleetwide CO_2 emissions are projected to continue rising through 2050. Transitioning the global vehicle fleet to zero-emission vehicle (ZEV) technologies is crucial to decarbonizing road transport and meeting climate goals. The governments of the ZEV Transition Council (ZEVTC) account for about half of new vehicle sales and include some of the world's most important centers of automotive design and manufacturing as well as some of the largest donors of development assistance. These governments have committed to accelerating the global ZEV transition. Recent policy advances made by ZEVTC governments will substantially reduce emissions, but not by enough to meet global climate goals. For this, the ZEVTC needs a truly global approach.

This paper makes recommendations on how ZEVTC governments can work together to accelerate such a global transition to zero-emission vehicles. In order to arrive at these suggestions, this briefing summarizes the state of the ZEV market and policies; quantifies benefits of recent policy developments by ZEVTC governments; analyzes opportunities and barriers in emerging markets and developing economies (EMDEs); and assesses the additional mitigation potential and need under an accelerated global ZEV transition.

State of the ZEV market and policies

In 2020, the global average sales share of ZEVs reached almost 3% for cars, 4% for buses, and 1% for vans, but remained below 1% for medium and heavy trucks. Among ZEVTC markets, ZEV sales reached almost 3% for cars, crept above 1% for vans, and reached almost 12% for buses.

ZEV sales shares outside the ZEVTC markets and China average only a fraction of a percent for all vehicle types. Among EMDEs, a few countries have made progress increasing ZEV uptake particularly for urban buses (e.g., Chile, 15%) and two-wheelers (e.g., Vietnam, 8%). No EMDE had a ZEV market share greater than 1% for cars.

ZEVTC governments made significant policy progress between November 2020 and August 2021. Approximately 30 major CO_2 and ZEV regulations have been adopted by ZEVTC governments and China. A similar number of ZEV policies and targets have been announced. At least 17 policies are expected to be proposed by these governments in the next two years.

Some EMDEs have introduced policies that echo the five major policy levers identified in the ZEVTC markets to accelerate the ZEV transition. EMDEs have also taken actions to further develop their domestic ZEV industry, develop market-based solutions, and leverage international support. It will take time for these recent changes to influence ZEV market uptake.

Phase-out targets and CO_2 standards and ZEV regulations are major gaps in the ZEV policy frameworks of EMDEs. Only a few EMDEs have set phase-out targets for specific vehicle segments. Few EMDEs have CO_2 standards and ZEV regulations. Similarly, only some EMDEs provide strong fiscal incentive programs, although ZEVs are not cost competitive in most, and infrastructure support is limited.

In terms of financing the transition, many EMDEs are collaborating with and incentivizing international manufacturers to build domestic manufacturing and assembly capacity; prioritizing specific vehicle segments for electrification; and

introducing electric fleets and expanding purchase options through e-mobility businesses. While EMDEs in all regions are receiving international grants, loans, and technical support for the ZEV transition, there is a significant gap in financial support. Over the past five years, 37 EMDEs received in total approximately US$163 million in international support specifically for ZEVs, which is only 6.5% of the level of funding (US$2.5b) we estimate is needed over the next five years to adequately support the early phase of the ZEV transition in EMDEs.

In addition to the common barriers to ZEV transition faced by all countries, EMDEs also face challenges with ZEV regulatory frameworks, fiscal and financing mechanisms, imports of low-cost used internal combustion engine vehicles (ICEVs), and the need to build technical capacity. These barriers stand out in priority for EMDEs compared with advanced economies, although the heights of barriers vary among countries and regions.

Benefits of recent policy developments by ZEVTC governments

Global vehicle CO_2 emissions are still on a growth trajectory without further policy action. ZEVTC governments could make a significant dent in this CO_2 emission trajectory by implementing recently announced and proposed policies (Figure ES-1). In doing so, ZEVTC governments could reduce their vehicle CO_2 emissions in 2050 to 42% below 2020 levels. Light-duty vehicles account for 88% of these expected CO_2 reductions.

But absent further policy action, vehicle CO_2 emissions in EMDEs are projected to double by 2050 and could surpass those of ZEVTC members between 2035 and 2040. This is projected to lead to net growth in global vehicle CO_2 emissions even assuming ZEVTC governments implement recently announced and proposed policies.

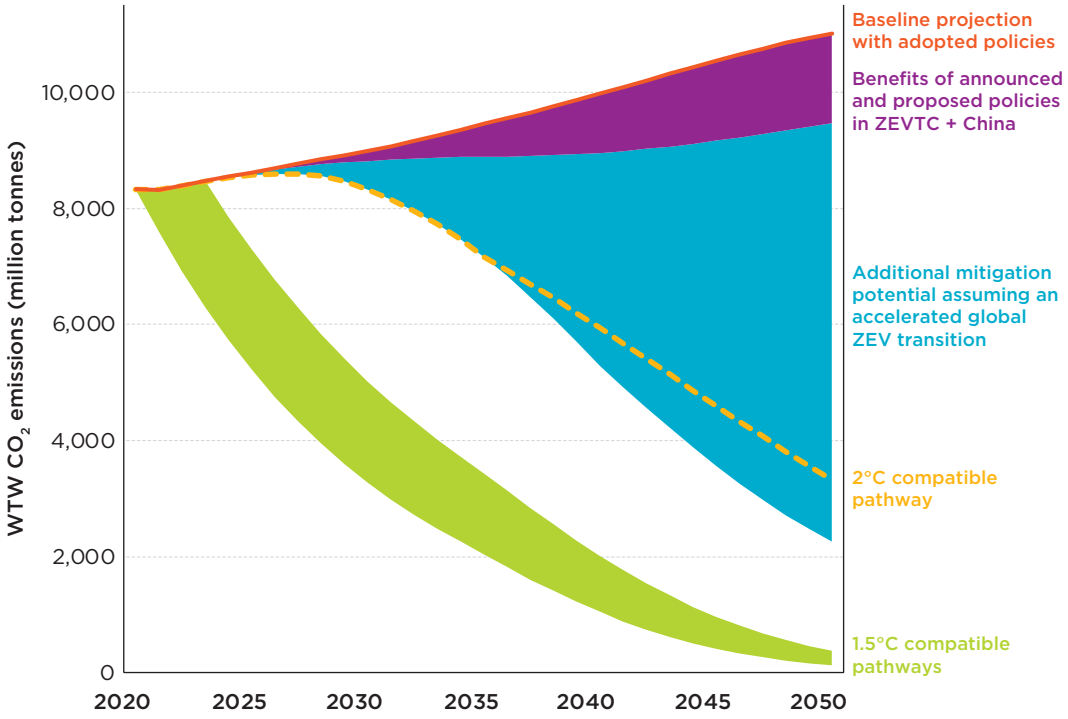

Figure ES-1. Global well-to-wheel (WTW) CO_2 emissions from cars, vans, trucks, and buses compared to 1.5°C and 2°C compatible emissions pathways.

Additional mitigation potential and need under an accelerated global ZEV transition

Compared to a Baseline that includes adopted and finalized policies, an Ambitious scenario that assumes technically feasible scale-up of ZEV production and market uptake driven by strong ZEV policies globally could avoid 99 Gt CO_2 cumulatively from 2020 to 2050, which is equivalent to nearly 12 years' worth of global vehicle CO_2 emissions at 2020 levels. ZEVTC markets account for 42% of this mitigation potential; the 117 EMDEs that we analyzed account for 34%; China accounts for 20%; and the rest of world accounts for the remainder.

An accelerated global ZEV transition is crucial to put the global vehicle fleet on a pathway that is consistent with climate goals. For a 67% chance to limit warming to 1.5°C and 2°C, global economy-wide CO_2 emissions must be limited to 360 Gt CO_2 and 1,110 Gt CO_2, respectively, from the start of 2021 until reaching net zero. Assuming vehicles use a fraction of the economy-wide carbon budget that is proportional to their well-to-wheel CO_2 emissions in 2020, achieving the Ambitious scenario globally could eliminate the gap between projected vehicle CO_2 emissions under current policies and a 2°C pathway. There is little margin for error to still limit warming to 1.5°C, since the carbon budget will be exhausted in less than a decade at the current rate. To close the gap with 1.5°C, vehicle CO_2 emissions would need to be reduced on the order of 40%–60% by 2030, 80%–90% by 2040, and to near zero by 2050.

The ZEV leapfrog in EMDEs is necessary for a truly global ZEV transition but challenging. Regional and international collaborations are needed for EMDEs to develop ZEV transition roadmaps, CO_2 standards and ZEV regulations, local industry supply chains, and other effective policies and programs. ZEVTC governments have a crucial role to play in the global ZEV transition beyond their borders including contributing to drive down ZEV technology costs, providing financial and technical assistance, and deepening regional dialogues for knowledge exchange.

Recommendations for ZEVTC governments to accelerate the global ZEV transition

1. **Adopt and implement the five major policies identified previously to work toward 100% ZEV sales for light-duty vehicles by 2035 and heavy-duty vehicles by 2040.** In particular, set phase-out targets with aligned policies that achieve ZEV sales shares of:

    - at least 60%–75% for cars, vans, and buses and 30%–40% for trucks by 2030
    - 90% for cars, vans, and buses and 60%–75% for trucks by 2035
    - 90% for heavy trucks and 100% for all other vehicle types by 2040
    - 100% for heavy trucks by 2045

In addition, work to reduce the gap with a 1.5°C scenario by accelerating ZEV transitions for specific fleets and looking to other types of policy measures to reduce vehicle travel. Large-scale ZEV penetration in leading markets will significantly bring down the costs of ZEV technology and increase ZEV model availability and manufacturing capacity. That will lower costs for the rest of the world to get access to ZEVs and related technologies.

2. **Support the creation of ZEV dedicated financing facilities via existing and new programs and initiatives to provide effective financial assistance to EMDEs and act to shift investments in ZEVs abroad.** There is a need to closely work with the multilateral international organizations to ensure that relevant funds are spent in a cost-effective approach and that the efforts are not duplicated**.** The funding could be used to: (a) create ZEV-specific facility dedicated to providing financial and technical support to global ZEV deployment; (b) finance electrification of targeted fleets, such as public transportation and two- and three-wheelers in EMDEs; (c) identify and support innovative and effective business and finance models to support the e-mobility transition of both light and heavy-duty vehicles; (d) support development of bankable e-mobility projects. In addition, consider options to ensure the export of used vehicles to EMDEs supports an accelerated global ZEV transition and is in line with the Paris Agreement goals.

3. **Establish a working group on the global ZEV transition as an enduring forum to engage with non-ZEVTC countries, especially EMDEs, and form regional collaborations to reduce disparities in the ZEV transition.** The working group could engage with the EMDEs to address key challenges for the ZEV transition and contribute to key priority regional efforts: (a) formulation and implementation of the appropriate measures to accelerate the ZEV transition for EMDEs; (b) establishment of technical standards for safety and quality assurance of new and used ZEVs, batteries, and infrastructure; (c) formation of regional collaborations among EMDEs to regulate import of used ICEVs and ensure uniformity of region-wide development in charging infrastructure and technical standards; (d) building capability to localize the ZEV supply chain within respective regions and countries; and (e) sharing technological know-how and building capacity needed for the ZEV transition.

Introduction

Transitioning the global vehicle fleet to zero-emission vehicle (ZEV) technologies is crucial to decarbonizing road transport and meeting climate goals.[1] ZEVs—specifically battery-electric vehicles (BEVs) and hydrogen fuel cell electric vehicles (FCEVs)—are the only technologies that can achieve deep decarbonization of road transport on a lifecycle emissions basis at sufficient scale.[2] Plug-in hybrid electric vehicles (PHEVs) still produce exhaust emissions when operating in charge-sustaining mode. Since this paper focuses on the policies and technology deployment needed to fully decarbonize light- and heavy-duty vehicles, PHEVs are not counted as ZEVs in this paper.

There has been significant progress toward the ZEV transition over the past two years, both in terms of market growth and development of policies necessary to support the transition. But that progress has been uneven. Much of it has occurred in countries represented in the ZEV Transition Council (ZEVTC), less in emerging markets and developing economies (EMDEs).[3] The purpose of this briefing is to summarize the current state of the ZEV market and policies; quantify the CO_2 benefits of recent policy developments by ZEVTC governments;[4] analyze opportunities and barriers in EMDEs; assess the additional mitigation potential and need under an accelerated global ZEV transition; and determine how ZEVTC governments can contribute to a global transition.[5]

Current state of ZEV uptake

In 2020, the global average sales share of ZEVs reached almost 3% for cars, 4% for buses, and 1% for vans but remained a fraction of a percent for medium and heavy trucks. Among ZEVTC markets, ZEV sales shares reached almost 3% for cars and 12% for buses. In Norway more than half of car sales were ZEVs, while in the Netherlands two of every three bus sales were. Vans lag cars in ZEV sales shares. Although several markets have achieved ZEV sales shares of several percent for medium trucks (e.g., Germany, at 6.5%), none have surpassed 0.5% for heavy trucks.

Meanwhile, ZEV sales shares outside the ZEVTC markets and China average only a fraction of a percent for all vehicle types. Among EMDEs, a few countries have made progress increasing ZEV uptake, particularly in the urban bus and two-wheeler segments. In 2020, ZEV sales shares among EMDEs reached as high as 15% for buses in Chile and 8% for two-wheelers in Vietnam. ZEV uptake for cars is low, with the highest ZEV market share among EMDEs at 0.9% in Ukraine. Most other EMDEs have low or no ZEV sales.

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1 UK Climate Change Committee, "The role of zero emissions vehicles in global pathways meeting the Paris Agreement" (July 2021), https://www.theccc.org.uk/publication/the-role-of-zero-emissions-vehicles-in-global-road-transport-pathways/

2 Stephanie Searle, Georg Bieker, and Chelsea Baldino, *Decarbonizing road transport by 2050: Zero-emission pathways for passenger vehicles* (Washington, DC: ICCT, 2021) https://theicct.org/publications/zevtc-decarbonizing-by-2050-jul2021

3 This briefing is based in part on Tanzila Khan, Zifei Yang, Sumati Kohli, and Joshua Miller, *An overview of ZEV deployment in emerging markets* (Washington, DC: ICCT, forthcoming) an analysis of ZEV policies in 117 emerging markets and developing economies, which include middle-income and low-income countries. That paper also analyzes ZEV policies for select high-income countries that are not ZEVTC members.

4 China is not a ZEVTC member but is also considered given its status as the world's largest vehicle market.

5 In addition to Khan et al. *An overview of ZEV deployment in emerging markets*, this briefing is based on analysis detailed in Arijit Sen and Joshua Miller, *Emissions reduction benefits of a faster, global transition to zero-emission vehicles* (Washington, DC: ICCT, forthcoming)

Table 1. ZEV share of total sales in 2020.

Region	Car	Van	Bus	Medium truck	Heavy truck
Canada	2.30%	0.00%	1.70%	0.00%	0.00%
Denmark	7.20%	1.50%	2.30%	0.00%	0.40%
France	6.70%	2.20%	2.60%	1.90%	0.00%
Germany	6.70%	3.20%	5.90%	6.50%	0.10%
India	0.20%	0.00%	0.40%	0.00%	0.00%
Italy	2.40%	1.20%	0.70%	0.10%	0.00%
Japan	0.40%	0.10%	0.10%	0.00%	0.00%
Mexico	0.20%	0.00%	0.00%	0.00%	0.00%
Netherlands	20.50%	2.80%	69.40%	3.40%	0.20%
Norway	54.30%	8.00%	16.50%	0.10%	0.40%
Republic of Korea	1.80%	0.00%	0.00%	0.00%	0.00%
Spain	7.20%	1.50%	1.80%	0.20%	0.00%
Sweden	9.50%	6.10%	9.90%	0.00%	0.30%
United Kingdom	6.60%	1.80%	6.20%	2.80%	0.10%
United States	1.70%	1.00%	0.60%	0.00%	0.00%
ZEVTC average	2.90%	1.10%	11.70%	0.80%	0.00%
EU-27 average	5.30%	2.00%	6.10%	3.50%	0.00%
China	5.00%	2.30%	22.90%	1.30%	0.20%
Rest of world average	0.40%	0.20%	0.00%	0.00%	0.00%
Global average	2.90%	0.90%	3.70%	0.50%	0.00%

ZEV share of total vehicle sales 0.0% 69.4%

ZEV policy developments in ZEVTC and major vehicle markets

In a discussion paper prepared earlier for the ZEVTC, ICCT identified five major policy levers that ZEVTC governments have put in place to accelerate the ZEV transition: ICEV phase-out targets, ZEV regulations and CO_2 standards, fiscal incentives, charging infrastructure, and demand-side measures.[6] Phase-out targets are an important first step to give clear direction to industry and all levels of government to develop supporting policies (e.g., the other four policy levers). In our view, ZEV regulations or equivalent CO_2 standards (i.e., a limit of 0 grams CO_2 per km) are the most certain policy lever to achieve 100% ZEV sales, since vehicle manufacturers must meet the standards or face penalties that exceed the costs of compliance. These requirements should ramp up annually from current market shares to 100% ZEV sales to achieve a

6 Dale Hall, Yihao Xie, Ray Minjares, Nic Lutsey, Drew Kodjak, *Decarbonizing road transport by 2050: Effective policies to accelerate the transition to zero-emission vehicles* (Washington, DC: ICCT, forthcoming).

smooth transition and maximize cumulative emissions benefits.[7] The remaining levers—incentives, infrastructure, and demand-side measures—serve to make the transition more affordable, convenient, and attractive (and in some cases, required) for vehicle buyers and operators.

ZEVTC governments made significant policy progress between November 2020 and August 2021. We group their recent policies and announcements into three categories: (1) adopted or finalized policies, which are included in our Baseline scenario; (2) announced or proposed policies, which are included in our Progress to Date scenario; and (3) policies under development, which are identified but not modeled.[8]

Adopted or Finalized Policies: As of August 2021, approximately 30 major CO_2 and ZEV regulations had been adopted by ZEVTC governments and China.[9] One such program, for example, is California's Advanced Clean Trucks rule, which requires manufacturers to meet minimum ZEV sales shares of 75% for Class 2b–3 pickups and vans, 55% for Class 4–8 trucks, and 40% for Class 7–8 tractors by 2035.

Announced or Proposed Policies: An additional 30 or so major new ZEV policies and targets have been announced by ZEVTC governments and China but are yet to be finalized and made legally binding. Examples of these are the European Commission's proposed CO_2 standards that would set a target of 0 grams CO_2 per km for new cars and vans in 2035; California's and Canada's goals for 100% ZEV sales for light-duty vehicles by 2035; and the United Kingdom's consultations for CO_2 standards to achieve 100% ZEV sales for light-duty vehicles by 2035 and for heavy-duty vehicles by 2040. These policies must be finalized and implemented if they are to achieve emissions reductions.

Policies under Development: At least 17 policies are expected to be proposed by ZEVTC governments and China within the next two years. Examples of these are the European Commission's expected revised CO_2 standards for heavy-duty vehicles (HDVs); United States Phase 3 HDV greenhouse gas emission standards; and new energy vehicle (NEV) standards for commercial vehicles in China. These expected policies present a substantial opportunity to further accelerate the ZEV transition. Of course, to achieve emission reductions, these policies would need to be proposed, finalized, and implemented effectively.

ZEV policy developments in EMDEs

Some EMDEs have introduced policies that echo the five major policy levers identified in the ZEVTC countries to accelerate the ZEV transition.[10] EMDEs have also taken actions to promote domestic ZEV industries, develop market-based solutions, and leverage international support. In many cases these actions were taken in 2020 and 2021, and it will take time for them to be reflected in ZEV market uptake.

ICEV phase-out targets and **CO_2 standards and ZEV regulations** are two major gaps in the ZEV policy frameworks of EMDEs. Only a few EMDEs have set ICEV phase-out

7 Joshua Miller and Arijit Sen, "Details matter: The outsized climate benefits of setting annual targets for new cars in Europe," https://theicct.org/blog/staff/details-matter-annual-targets-europe-jul2021

8 Sen and Miller, *Emissions reduction benefits of a faster, global transition to zero-emission vehicles.*

9 The full list of policies is provided in Sen and Miller, *Emissions reduction benefits of a faster, global transition to zero-emission vehicles*.

10 Khan et al., *An overview of ZEV deployment in emerging markets*.

targets for specific vehicle segments. Countries with ICEV phase-out plans for new vehicles include Cape Verde (passenger cars by 2035 and urban buses by 2040), Chile (LDVs and urban buses and taxis by 2035, and freight transportation and intercity buses by 2045), Costa Rica (LDVs by 2050), Colombia (urban buses by 2035), Ecuador (public transportation by 2025), and Israel (private vehicles by 2030). Costa Rica has a plan for 100% ZEV stock for buses and taxis by 2050. Very few EMDEs have in place CO_2 standards and ZEV regulations, which are the most certain and effective policy mechanisms for ensuring a growing share of ZEVs are available for purchase. Only Brazil and Saudi Arabia have fuel economy standards.

Fiscal incentives and infrastructure support exist in many EMDEs. However, only some countries provide very strong incentive programs (e.g., Cape Verde, Belarus, Thailand) whereas ZEVs are still far from cost competitiveness in most countries. Infrastructure support remains at an initial development phase in most of these countries. A few countries—such as Thailand, Belarus, and Kazakhstan—have installed several hundred charging stations and have more under development, although most have only small-scale operations or pilot programs.

Demand-based policies in EMDEs are influenced by travel preferences. Faster ZEV transitions are happening for buses and two- and three-wheelers—the predominant modes of passenger transport—as well as in government fleets. Some Latin American countries have introduced electric buses through fleet purchase requirements (Costa Rica, Colombia) and by facilitating and financing pilot programs and public procurement (Colombia, Chile). ASEAN countries like Vietnam have stimulated electric two-wheeler sales by supporting domestic ZEV manufacturing and replacement programs. Yet EMDEs in general face limited public awareness of ZEV technology, benefits, and usage, with few examples of ZEV promoting events, campaigns, demonstrations, and learning centers. Raising public awareness is also a challenge in the ZEVTC countries and could be an area of collaboration with EMDE countries.

Supply-based policies are driven by individual countries' motivation for transitioning to ZEV technology. EMDEs with important auto manufacturing sectors (Thailand, Indonesia, Malaysia) or significant raw materials resources (Indonesia) are offering incentives to promote local ZEV manufacturing and assembly industries. Many countries are collaborating with international EV manufacturers to establish manufacturing and assembly capacity for EVs, batteries, and other EV components.

Innovative e-mobility businesses and **international support** are important for the ZEV transition in EMDEs, because of the economic constraints that exist in those regions. E-mobility startups and dealerships are emerging in many African countries, particularly for two- and three-wheelers. These businesses are introducing electric fleets to ride hailing, car sharing, and delivery services and expanding purchase options to vehicle leases and battery renting/swapping for electric two- and three-wheelers. Published information shows that countries across all regions are receiving grants, loans, and technical support for the ZEV transition from international agencies as well as philanthropic and financing institutions. Support areas include direct technical support, policy interventions, pilot projects, research and development, market-based solutions, and loan service.

CO_2 benefits of announced policies in ZEVTC markets

We modeled the CO_2 reductions expected to flow from policies recently announced and proposed by ZEVTC governments.[11] These CO_2 reductions are shown as the wedges between the Baseline and Progress to Date scenarios in Figure 1. **In all markets, these reductions are contingent on further developing ZEV regulations and CO_2 standards as well as other ZEV policies to support implementation.**

ZEVTC as a whole: If ZEVTC governments follow through on recently announced and proposed policies, they could reduce annual vehicle CO_2 emissions by 42% from 2020 to 2050, compared to a projected 14% decrease without further policy action. Light-duty vehicles account for 88% of these expected CO_2 reductions—14.5 Gt CO_2 of the 16.5 Gt CO_2 reduction in the Progress to Date scenario. Details are given in the following summaries for each individual ZEVTC market.

Canada: Canada's target of 100% zero-emission LDV sales by 2035 could reduce CO_2 emissions by 43% from 2020 to 2050. This national target incorporates and accelerates similar targets set by Quebec (2035) and British Columbia (2040).

European Union:[12] The Baseline for the EU27 includes currently adopted CO_2 standards for cars (-37,5% from 2021–2030), vans, and trucks. The European Commission's proposed CO_2 standards for cars and vans would go substantially further, requiring 100% ZEV sales in 2035. As a result of the proposed policy, CO_2 emissions are projected to fall by 63% from 2020 to 2050. These standards would incorporate and accelerate phase-out targets announced by Denmark (2035), France (2040), Germany, Italy, and Spain. With a ZEV sales share already above 20% for cars, the Netherlands is making progress toward its more ambitious target of 100% zero-emission car sales in 2030. The European Commission intends to propose revisions to its heavy-duty vehicle CO_2 standards in 2022, which presents a significant opportunity to further reduce vehicle emissions.

India: India has the fastest-growing vehicle fleet among ZEVTC members: growing demand for passenger and freight activity is projected to more than double India's vehicle CO_2 emissions through 2050. India has adopted first-phase efficiency standards for LDVs and HDVs, and India's transport minister has committed to achieve 30% zero-emission car sales by 2030. Next-phase efficiency standards, ZEV fiscal incentives, state-level EV policies, and EV industrial development policies each present opportunities to accelerate India's ZEV transition.

Japan: Japan's Baseline includes adopted efficiency standards for passenger cars to 2030 and for heavy-duty vehicles to 2025, which are projected to reduce CO_2 emissions by 35% from 2020 to 2050. Japan's 2030 targets for electric and hybrid cars are expected to be largely achieved with these adopted standards.

Mexico: Mexico's Baseline shows the second-highest rate of projected growth in CO_2 emissions among ZEVTC members, in large part because LDV efficiency standards have not been updated since 2016 and the government has yet to adopt HDV efficiency standards. Nonetheless, Mexico's Secretariat of Environment and Natural Resources

11 Many of these policies have been adopted or announced since the ZEVTC first convened in November 2020; however, some were adopted or announced between 2018 and 2020.

12 While Denmark, France, Germany, Italy, Netherlands, Spain, and Sweden are also individual members of the ZEVTC, the model results for these countries are grouped with EU27 countries for the sake of brevity. Sen and Miller, *Emissions reduction benefits of a faster, global transition to zero-emission vehicles.*

has set a target of 100% plug-in hybrid and ZEV sales for LDVs and HDVs by 2050. If future policies contribute to steady annual growth in ZEV sales from today rather than waiting until the 2040s, achieving this target could peak emissions in 2040 and achieve a 15% reduction from 2020 levels in 2050.

Norway: As a member of the European Economic Area, the European Union's CO_2 standards also apply in Norway. Yet Norway has achieved its leading ZEV sales shares for cars and vans largely with the aid of fiscal incentives and other non-regulatory measures. Norway's ZEV sales targets are 100% for LDVs by 2025, 100% for urban buses in 2030 (also allowing biogas), 75% for coaches in 2030, and 50% for trucks in 2030. Achieving these targets would reduce CO_2 emissions by 66% from 2020 to 2050.

Republic of Korea: The Republic of Korea's Baseline includes adopted CO_2 standards for cars and vans to 2030. Its target of 33% ZEV car sales by 2030 is expected to be largely achieved with these adopted standards. These policies, along with deployment targets for FCEV buses and trucks, are projected to reduce CO_2 emissions by 16% from 2020 to 2050.

United Kingdom: The United Kingdom has announced consultations to end the sale of non-ZEV cars, vans, buses, coaches, and heavy commercial vehicles. These consultations target 100% plug-in hybrid and zero-emission LDV sales by 2030; 100% zero-emission LDV sales by 2035; and 100% zero-emission HDV sales by 2040. The consultations to end the sale of non-ZEV HDVs by 2040 set its emission trajectory apart from other ZEVTC members, several of which have similar LDV targets but less ambitious targets for HDVs. Following through on all of these targets would reduce CO_2 emissions by 76% from 2020 to 2050.

United States: The Baseline for the United States includes federal regulations for LDVs and HDVs along with CO_2 and ZEV regulations adopted by California and so-called Section 177 states that have adopted California's regulation in lieu of the federal governments. Key drivers of further CO_2 reductions are the Biden administration's target of 50% plug-in hybrid and zero-emission LDV sales in 2030 and targets set by California, 14 other states, and the District of Columbia to achieve 30% zero-emission HDV sales by 2030 and 100% by 2045. California's targets of 100% ZEV sales for LDVs and HDVs are more ambitious than California's currently adopted rules; the eventual effects on nationwide CO_2 emissions depend on the stringency of California's forthcoming regulations, how many other states adopt similar standards, and how closely federal regulations eventually resemble these rules. In sum, currently announced targets are projected to reduce CO_2 emissions by 57% from 2020 to 2050.

China: China is not a member of the ZEVTC but is included here because it is the world's largest vehicle market. China's national standards and announced NEV sales targets currently extend only to 2025. In the Progress to Date scenario, vehicle CO_2 emissions are projected to increase 63% from 2020 to 2050. More ambitious NEV plans have been adopted by Hainan Province and Shanghai Municipality; these extend to 2025 and 2030, respectively. National NEV standards for commercial vehicles and Stage 4 HDV efficiency standards are under development, which present opportunities for further CO_2 reductions.

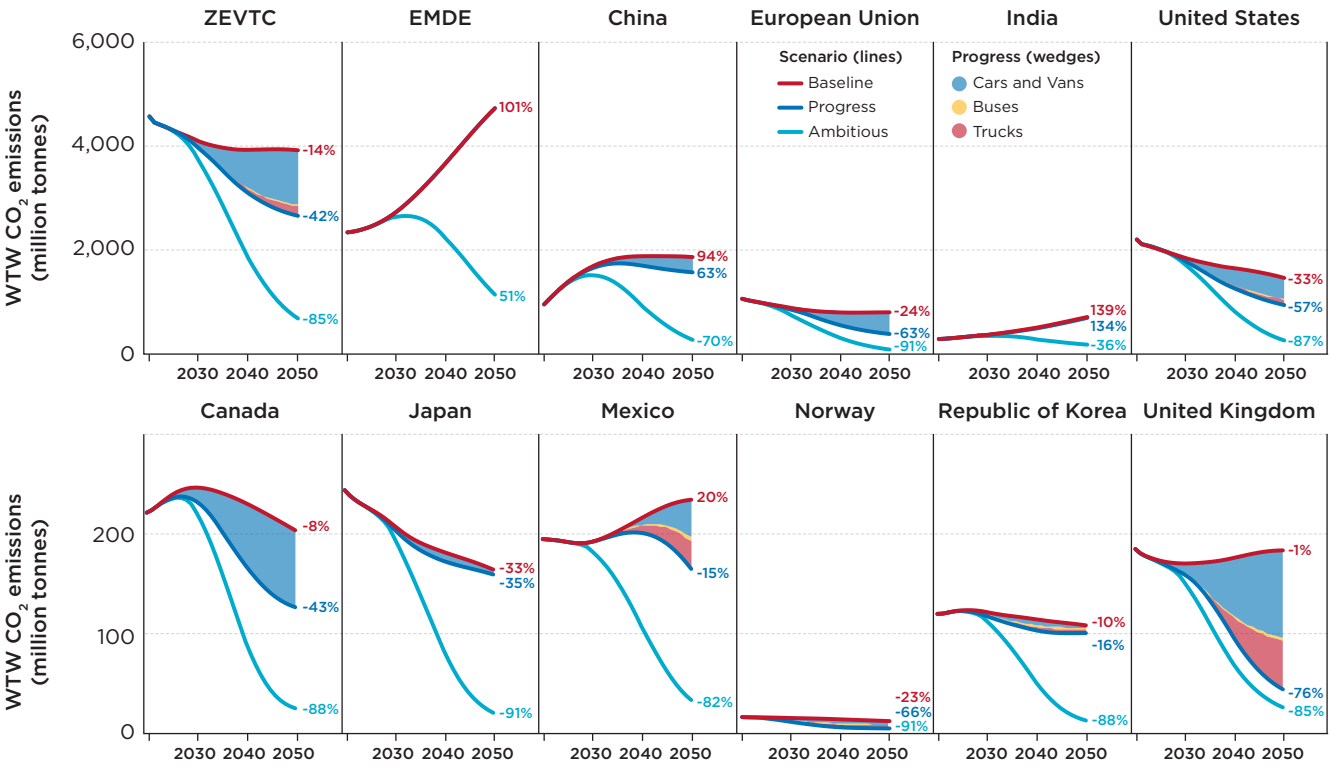

Figure 1. Projected WTW CO_2 emissions by scenario for ZEVTC members, major vehicle markets, and EMDEs. Data labels show the percent change from 2020 levels.

Outlook for an accelerated ZEV transition in the ZEVTC and EMDEs

While the achievements by ZEVTC members reflected in the Progress to Date scenario are impressive, they are not adequate to bring global vehicle emissions in line with climate goals. Therefore, we analyzed how much more could be achieved under an accelerated ZEV transition that includes technically feasible scale up of ZEV production and market uptake driven by strong ZEV policies. In this **Ambitious** scenario, we model the impacts of more rapid progress in leading markets, driven by more stringent and comprehensive ZEV policies. Under this scenario, increased economies of scale could help to bring down costs and commercialize ZEV technologies in all on-road segments. This in turn could enable other countries to accelerate their transitions to ZEVs by developing supportive policies and benefiting from the experiences of leading markets and more affordable and mature ZEV technologies.

The Ambitious scenario is designed to push the envelope but stay within our assessment of technical feasibility. We define technical feasibility as allowing sufficient lead time for governments to develop and implement ZEV policies (assuming political will), manufacturers to make investments and ramp up production capacity (assuming adequate policy drivers), and public and private entities to deploy adequate charging and hydrogen refueling infrastructure. To define the pace of the transition, we considered progressive positions put forth by governments and assessments by us and other researchers of technically feasible scale-up of ZEV production and policy-

driven market uptake, assuming political will exists to put these policies into place.[13] The results of this review are summarized in Table 2, which shows the range of ZEV sales shares assumed in the Ambitious scenario. Because the global transition will not happen at the flick of a switch, leading markets will need to move quickly—near the upper end of the ranges in Table 2. In the Ambitious scenario, we assume ZEV sales shares in leading markets reach 90%–100% for cars, vans, and buses and 60%–90% for medium and heavy trucks by 2035.

Table 2. Ambitious scenario assumptions. Ranges indicate variability in uptake among countries.

Vehicle type	2030	2035	2040	2045
Car	30%–75%	60%–100%	90%–100%	100%
Van	30%–75%	60%–100%	90%–100%	100%
Bus	60%–90%	90%–100%	100%	100%
Medium truck	30%–50%	60%–90%	90%–100%	100%
Heavy truck	20%–40%	40%–75%	75%–100%	100%

The ZEVTC could more than double the projected CO_2 benefits of the Progress to Date scenario by further accelerating its ZEV transition. Achieving the Ambitious scenario in ZEVTC markets could avoid 42 Gt CO_2 cumulatively and reduce annual CO_2 emissions by 85% from 2020 to 2050. For ZEVTC governments, securing Progress to Date would get them nearly 40% of the cumulative benefits in the Ambitious scenario. Securing the full benefits of the Ambitious scenario would require increasing the stringency and coverage of ZEV policies in nearly all ZEVTC markets. Achieving these benefits would depend on all ZEVTC governments setting phase-out targets with aligned policies that achieve ZEV sales shares of:

- at least 60%–75% for cars, vans, and buses and 30%–40% for trucks by 2030
- 90% for cars, vans, and buses and 60%–75% for trucks by 2035
- 90% for heavy trucks and 100% for all other vehicle types by 2040
- 100% for heavy trucks by 2045

In addition to accelerating its members' ZEV transition, the ZEVTC has an important role to play in accelerating a truly global transition, which is needed to meet climate goals. Without further policy action, vehicle CO_2 emissions in EMDEs are projected to double by 2050. If ZEVTC members follow through on the Progress to Date scenario but take no further action in EMDEs, vehicle CO_2 emissions in EMDEs could surpass those of ZEVTC members between 2035 and 2040. Yet that outcome can be avoided by also accelerating the ZEV transition in EMDEs. Achieving the Ambitious scenario in EMDEs could avoid 34 Gt CO_2 cumulatively and reduce annual CO_2 emissions by 51% from 2020 to 2050, despite continued growth in passenger and freight activity in these countries. These estimated CO_2 benefits for EMDEs are also conservatively low, since they do not capture two- and three-wheelers, which play a significant role in EMDEs.

The ZEV leapfrog in EMDEs is necessary but challenging. The necessity of accelerating the ZEV transition is compounded, in EMDEs, by the air pollution and

13 Sen and Miller, *Emissions reduction benefits of a faster, global transition to zero-emission vehicles.*

health impacts of ICEVs, which are felt acutely there and which a shift to zero-emission vehicles addresses radically and effectively. The challenges in EMDEs, in addition to the universal barriers of availability, affordability, convenience, and consumer awareness, come in the form of nonexistent ZEV regulatory frameworks, inadequate fiscal and financing mechanisms, imports of low-cost used ICEVs, and insufficient technical capacity. These barriers stand out in priority for EMDEs compared with advanced economies, although the heights of these barriers vary among countries and regions.[14]

To encourage adoption and investment in ZEV technology, regional efforts and international collaborations are needed for EMDEs to develop ZEV transition roadmaps, CO_2 standards and ZEV regulations, and the local industry supply chains.[15] Before ZEVs reach cost parity, EMDEs can reduce ZEV costs without imposing an extensive financial burden on government. Options to do so include introducing budget-neutral mechanisms that make high-emitters pay (e.g., feebates) or seeking international financing to fund targeted fiscal policies and innovative business models. EMDEs that largely import their new vehicles could form trade agreements with exporting countries to lower or waive import duties for ZEVs or ZEV components. Major importers of used vehicles could tighten standards for imported ICEVs while allowing imports of slightly used EVs that meet performance and safety standards. EMDEs could prioritize ZEV transitions of highly utilized fleets, such as shared mobility fleets or government-operated vehicles. EMDE governments could mobilize private-sector initiatives through partnerships with international automobile companies and/or through international financing.

There is a significant gap in international financing to support the ZEV transition in EMDEs. We estimate that 37 of the 117 EMDEs we analyzed received in total approximately $163 million USD in international support specifically for ZEVs over the past five years. To adequately support the early phase of the ZEV transition in EMDEs will require approximately $2.5 billion over the next five years, in our estimation, and that funding must extend to a far greater number of EMDEs. **ZEVTC governments have a crucial role to play in the global ZEV transition beyond their borders, including contributing to drive down ZEV technology costs, providing financial and technical assistance, and deepening regional dialogues for knowledge exchange.**

Climate implications of an accelerated global ZEV transition

An accelerated global ZEV transition—including ZEVTC markets, China, EMDEs, and the rest of the world[16]—is crucial to put the global vehicle fleet on a pathway that is consistent with climate goals. For a 67% chance to limit warming to 2°C, global

14 See Khan et al., *An overview of ZEV deployment in emerging markets*, for a comprehensive list of identified barriers and policy ideas.

15 ZEV supply chain includes the processes starting from raw material extraction to disposal including manufacturing, sourcing, services, recycling, reusing, and material recovery.

16 Rest of world includes Russia, Australia, and 41 other countries that are not ZEVTC members and do not meet the definitions of EMDEs used in this assessment.

economy-wide CO_2 emissions must be kept to 1,110 Gt CO_2 from the start of 2021 until reaching net zero. To keep warming below 1.5°C, emissions must be kept to 360 Gt CO_2.[17]

In 2020, cars, vans, buses, and trucks collectively emitted approximately 21% of global CO_2 emissions. The dotted line in Figure 2 illustrates a vehicle emissions pathway that is consistent with the remaining carbon budget for 2°C. The example 2°C pathway assumes vehicles use 21% of the global carbon budget from 2021 until reaching net zero.

There is little margin for error to still limit warming to 1.5°C, since the carbon budget will be exhausted in less than a decade at the current rate. Since the global vehicle fleet will take more than a decade to turn over, even if all new vehicles are ZEVs, it will likely need to use a greater fraction of the remaining carbon budget than its current fraction of emissions. The shaded green area in Figure 2 illustrates possible vehicle emissions pathways that are consistent with 1.5°C. These pathways assume vehicles use approximately 21% or 32%[18] of the remaining global carbon budget before they reach close to net zero around 2050.

An accelerated global ZEV transition could eliminate the emissions gap between projected vehicle CO_2 emissions under current policies and a 2°C pathway. If ZEVTC governments and China follow through on recent ZEV announcements but no further policy action is taken, global vehicle CO_2 emissions would be reduced substantially compared to the Baseline but still continue growing through 2050. Accelerating global ZEV uptake in line with the Ambitious scenario could avoid 99 Gt CO_2 cumulatively compared to the Baseline and reduce annual CO_2 emissions to 73% below 2020 levels by 2050.

Even under this Ambitious scenario for ZEVs, the emissions gap with a 1.5°C pathway would need to be closed by complementary in-sector policies coupled with faster reductions in other sectors. Examples of complementary policies could include accelerated zero-emission fleet transitions, maximizing uptake of efficiency technologies on remaining ICEV sales, avoid and shift policies, and faster decarbonization of the electricity grid.

17 We subtracted approximate global CO_2 emissions in 2020 from the carbon budgets in "Table SPM.2: Estimates of historical CO2 emissions and remaining carbon budgets." See: IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. Retrieved from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

18 50% more than vehicles' current share of anthropogenic CO_2.

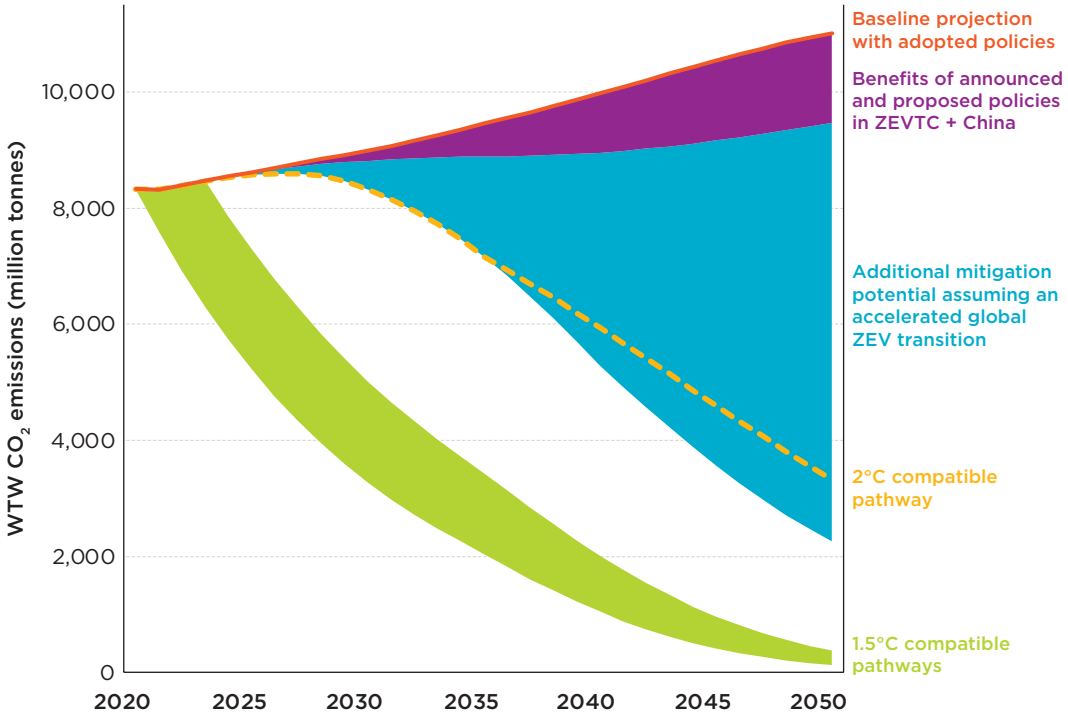

Figure 2. Global WTW CO_2 emissions from cars, vans, trucks, and buses compared to 1.5°C and 2°C compatible emissions pathways.

Conclusions

In this briefing, we summarized the current state of the global ZEV market and policies; quantified the benefits of recent policy developments by ZEVTC governments; assessed the additional mitigation potential and need under an accelerated global ZEV transition; and evaluated how ZEVTC governments can collaborate with EMDEs to achieve a global transition.

Several leading markets have achieved very high ZEV market shares for cars and buses, largely as a result of combining stringent CO_2 standards, ZEV rules, and strong fiscal incentives. Yet among ZEVTC markets, substantial disparities in ZEV policy frameworks and corresponding ZEV market shares persist. Medium and heavy trucks in particular still have very low ZEV uptake in all markets.

In the past several years, and particularly since the ZEVTC first convened in November 2020, the pace of ZEV policy developments has accelerated. To meet global climate goals, we recommend ZEVTC governments further accelerate their own ZEV transitions and collaborate with EMDEs to the same purpose. Ensuring an accelerated global ZEV transition could eliminate the gap between projected vehicle CO_2 emissions under current policies and a 2°C pathway. Other complementary policies are needed to reduce the emissions gap with 1.5°C.

Our analysis of ZEV deployment and policies in ZEVTC markets and EMDEs leads to several specific recommendations for how the ZEVTC and EMDEs can contribute to a truly global transition. These recommendations also take into account ideas

shared in a series of working-level roundtables with EMDE representatives. These recommendations are summarized as follows:

1. **Adopt and implement the five major policies identified previously[19] to work toward 100% ZEV sales for LDVs by 2035 and HDVs by 2040.** ZEVTC members have demonstrated significant Progress to Date, with even more policies under development. An important next step is to fully adopt and implement the policies underlying the Progress to Date scenario, and to seek additional reductions from policies under development. In addition, we recommend ZEVTC members work to reduce the gap with a 1.5°C scenario by accelerating ZEV transitions for specific fleets and looking to other types of policy measures to reduce vehicle travel. One important consequence of large-scale ZEV penetration in leading markets will be to significantly bring down the costs of ZEV technology and increase ZEV model availability and manufacturing capacity. As a result, the costs will be lower for the rest of the world to get access to ZEVs and related technologies (e.g., renewable electricity and green hydrogen production technologies).

2. **Support the creation of ZEV dedicated financing facilities via existing and new programs and initiatives to provide effective financial assistance to EMDEs and act to shift investments in ZEVs abroad.** There is a need to closely work with multilateral organizations to ensure that relevant funds are spent in a cost-effective approach and that the efforts are not duplicated. The funding could be used to: (a) Create a ZEV-specific facility, as an independent institutional capacity, solely dedicated to providing financial and technical support to global ZEV deployment; (b) Finance electrification of targeted fleets, such as public transportation and two- and three-wheelers in EMDEs; (c) Identify and support innovative and effective business and finance models to support the e-mobility transition of both light and heavy-duty vehicles; and (d) Support the development of bankable e-mobility projects. In addition, we suggest considering options to ensure the export of used vehicles to EMDEs supports an accelerated global ZEV transition and is in line with the Paris Agreement goals.

3. **Establish a working group on the global ZEV transition as an enduring forum to engage with non-ZEVTC countries, especially EMDEs, and form regional collaborations to reduce disparities in the ZEV transition.** The working group could engage with the EMDEs to address the key challenges for ZEV transition and contribute to the key priority regional efforts: (a) formulation and implementation of appropriate measures to accelerate the ZEV transition for EMDEs; (b) establishment of technical standards for safety and quality assurance of new and used ZEVs, batteries, and infrastructure; (c) formation of regional collaborations in EMDEs to regulate imports of used ICEVs and ensure uniformity of region-wide development in charging infrastructure and technical standards; (d) building capability to localize the ZEV supply chain within respective regions and countries; and (e) sharing the technological know-how and building capacity needed for the ZEV transition.

19 Hall et al., *Decarbonizing road transport by 2050: Effective policies.*

Glossary

Battery electric vehicles (BEVs)	Vehicles that run exclusively on electricity derived from on-board batteries, which are charged from an external charging station or Electric Vehicle Supply Equipment (EVSE).
CO_2 standards	Government regulations that set minimum levels of vehicle fuel efficiency or maximum emissions of vehicle carbon dioxide or other greenhouse gases.
Consumer awareness	Consumer familiarity and comfort with the characteristics of electric vehicles and the advantages of EV ownership.
Emerging markets and developing economies (EMDEs)	In this paper, we analyzed ZEV policies for 117 middle-income and low-income countries. These are referred to as EMDEs throughout.
Fleet purchase requirements	A regulation requiring that a minimum share of a fleet be zero-emission, as a stimulant to market demand. Most fleet purchase requirements today apply to transit buses and to fleets owned by governments.
Fiscal incentives	Government financial policies for promoting electric vehicle ownership. These are often divided into subsidies (such as tax credits, rebates, and exemptions from tolls) and vehicle tax reductions (which can be one-time or annual).
Heavy-duty vehicles (HDVs)	Medium and heavy commercial vehicles including buses and trucks whose maximum gross vehicle weight rating is greater than 3500 kg (3856 kg in the US and Canada).
Hydrogen fuel cell electric vehicles (FCEVs)	Vehicles powered by hydrogen, which is converted to electricity by an onboard fuel cell.
Internal combustion engine vehicles (ICEVs)	Vehicles powered by an internal combustion engine, most commonly fueled by diesel, gasoline, natural gas, or biofuels.
Light-duty vehicles (LDVs)	Cars or trucks whose maximum gross vehicle weight rating is less than 3500 kg (3856 kg in the US and Canada). These are typically passenger cars, vans, and light trucks.
New Energy Vehicles (NEVs)	The label used in China for electric vehicles (EVs), including BEVs, FCEVs, and PHEVs.
Plug-in hybrid electric vehicles (PHEVs)	Vehicles that can operate on electricity from an onboard battery, but also have an internal combustion engine as a backup source of power. PHEVs charge their batteries from an external charging station or EVSE.

Shared mobility	Encompassing buses and minibuses, taxis, ride hailing and car sharing fleets, and shared two -and three-wheelers
Targets	The aspirational visions set by a government to signal future policy directions. In this document targets refer to goals set to ensure that sales of zero-emission vehicles, as a share of total vehicle sales, are increasing. Targets assist manufacturers of zero-emission vehicles and related infrastructure in planning their products and investments.
Zero-emission vehicles (ZEVs)	Vehicles, such as BEVs and FCEVs, that produce zero exhaust emissions. PHEVs, which still produce exhaust emissions when operating in charge-sustaining mode, are not counted as ZEVs in this paper.
ZEV regulations	Regulations requiring that ZEVs account for a certain share of new vehicle sales by each automaker, with the share increasing over time.