

ACCELERATING THE ZEV MARKET
IN THE U.S. AND CHINA



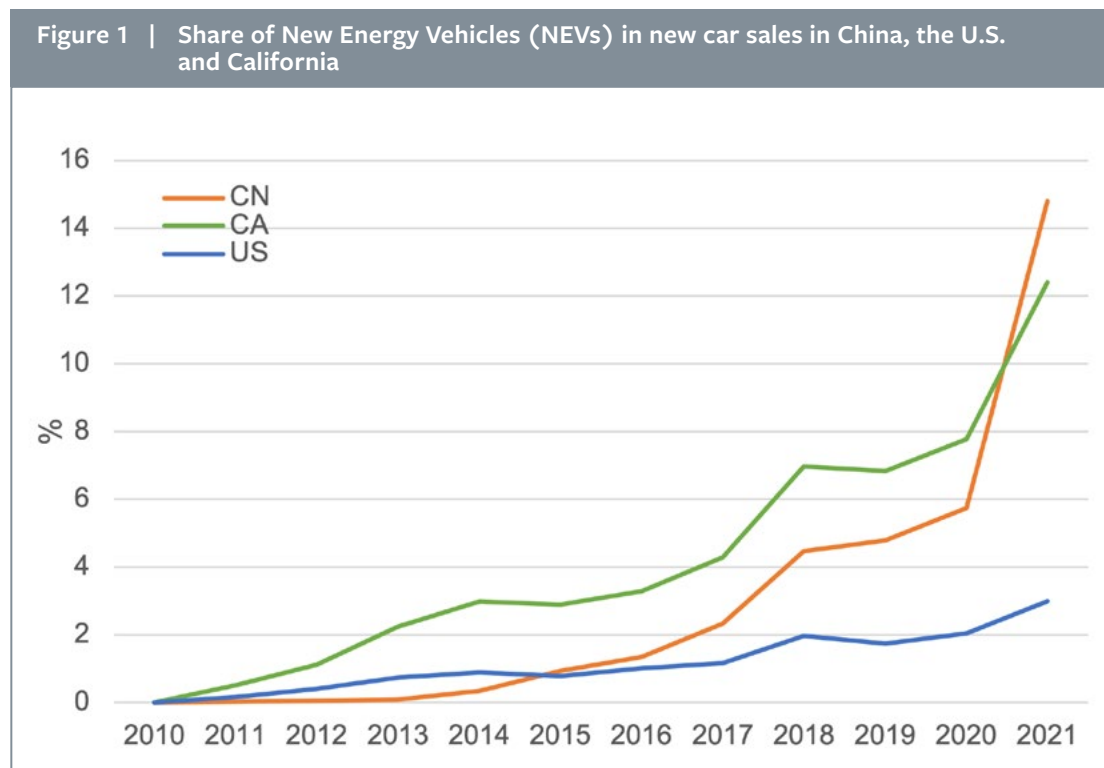
ACCELERATING THE ZEV MARKET IN THE U.S. AND CHINA

Yunshi Wang, University of California Davis*
Xiuli Zhang, University of California Davis*
Hui He, International Council on Clean Transportation*
Dan Sperling, University of California Davis*

* Organizations are noted for affiliation purposes only. This paper represents authors' views, and not necessarily those of their institutions.

BACKGROUND AND CHALLENGES

Together, the U.S. and China accounted for over 50 percent of the global vehicle market in 2021 (OICA, 2022). The two countries together dictate vehicle technology development trends and consumer preferences for vehicles. California and its Zero-emission Vehicle (ZEV) Alliance states led the world in pioneering ZEV policies and ZEV deployment in the early 1990s. In 2021, ZEV sales accounted for 4 percent of the total light-duty vehicle (LDV) sales in the United States (Minos, 2022), doubling the previous year's market share. California, however, achieved the ZEV penetration rate of 12.4% (CA gov, 2022).



Data Source: IEA, CEC

China now leads the world in total ZEV adoption both in passenger vehicles and especially in commercial vehicles. China's New Energy Vehicles (NEV) account for about 50 percent of global sales. In China, 3.5 million NEVs were sold in 2021, with a 13.4 percent of the market penetration rate (15.5 percent penetration of passenger vehicles). If China's NEV sales were a market alone, it would be ranked the fourth largest automotive market in the world, behind China, the U.S., and Japan. With 2.6 million units sold in the first half of the year, the country is on the trajectory of 5 million NEV sales in 2022.

The U.S. and China started to engage in close cooperation and information sharing on ZEV policies and academic research in 2009 when then the U.S. Secretary of Energy Steven Chu and the Chinese vice Premier Liu Yandong agreed to strengthen cooperation on climate change and clean energy science and technology, with the establishment of the U.S.-China Clean Energy Research Center (CERC). Clean Vehicle Center was one of the sub-centers under the CERC. Two years later, in California, under Governor Jerry Brown, California sped up its interactions with China. Current and former California Air Resources Board (CARB) officials visited China frequently, elaborating on ZEV policy's role in reducing smog in Los Angeles. On August 20th, 2015 in Asilomar, a joint delegation of Chinese officials from the National Development and Reform Commission, the Ministry of Industry and Information Technology, and the Ministry of Finance engaged in intensive discussion with CARB officials and international automotive executives, including those from Tesla and BYD, on the merits and issues of the ZEV Mandate in California and potentially in China. At the same time and in the same place, executives from Volkswagen confessed to then Chair of CARB Mary Nichols that diesel was in fact not a clean option. This ZEV policy workshop, along with many other efforts, led to China's formal adoption of the California-style NEV Dual-credit Policy in September 2017, opening up the twenty-six million automobiles, or 32 percent of the global vehicle market to accelerated adoption of ZEVs.

In short, the cooperation between the two countries have contributed to the global ZEV deployment and has, over the years, created a reservoir of goodwill among a generation of government officials, policy advisors, nongovernmental organization (NGO) staffers, and researchers in both countries.

Comparison of Goals, Policies and Issues in Both Countries

The U.S. government policy needs to be strengthened with targets raised to meet the 2050 carbon neutrality goal for the fleet. This requires a target of 100 percent ZEV market share before 2040.

California and the 17 states that have adopted all or part of California's low-emission and ZEV regulations have much stronger commitment, usually backed by laws and regulations. At least ten states are expected to follow California's new ZEV mandate for 2026-2035 (ACC II), which will likely affect 30-40 percent of the U.S. market (Tal, Davis, & Garas, 2022). California has proven that if the government sets up a bold goalpost, the market will follow and start-ups will spring up to meet, and even create, new demand.

The Chinese government has set the overall targets of peak CO₂ emissions before 2030 and carbon neutrality before 2060 (China State Council, 2021), and is developing a sectoral carbon peaking plan for transportation for the near term. China has yet to set any long-term decarbonization targets for the transportation sector. In the short term, the NEV sales shall reach about 20 percent of all new vehicle sales in 2025 and about 40 percent in 2030 (China State Council, 2020). The 2025 target has already been reached in the first half of 2022. The NEV sales account for 21.6 percent of the total new sales, and the penetration rate in passenger vehicles is even higher, at 24 percent. The newly published Dual-credit Policy (proposal for public comments) implies that the NEV market share will probably reach 33-40 percent by 2025. It is urgent that the government set new 2025 and 2030 goals in line with the carbon neutrality commitment and the promising market trend to provide the industry with a flag to follow.

I. Key Policies in the United States

- The Environmental Protection Agency's (EPA's) national greenhouse gas (GHG) emissions standards for vehicles. With more stringent GHG standards for vehicle travel

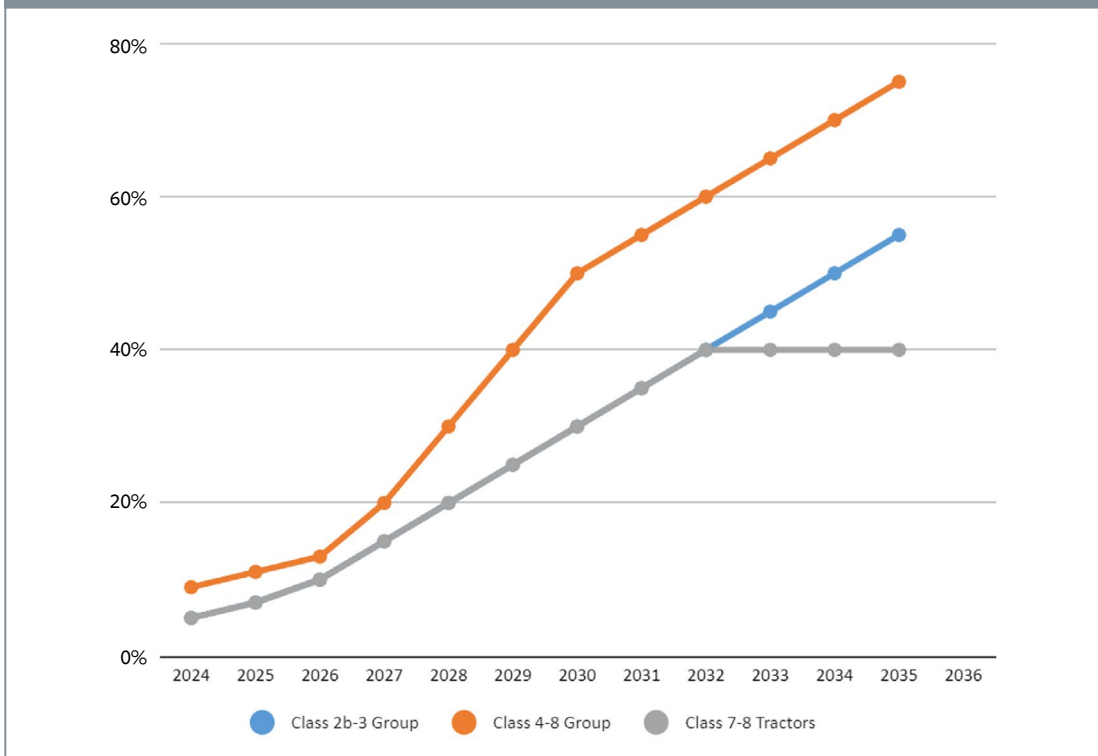
miles per gallon, EPA could potentially compel Original Equipment Manufacturers (OEMs) to produce more ZEVs as the European Union’s CO₂ emission performance standards for cars have done in Europe.

- The other important policy on ZEV deployment in the U.S. is the \$7,500 tax credit for a new ZEV buyer and \$4,000 for a used ZEV buyer, with income below a certain level, in a new policy proposal (Friedman & Plumer, 2022) passed by the Congress.
- The \$7.5 billion for electric vehicle (EV) charging infrastructure (The White House, 2022) to build out the first-ever national network of 500,000 electric vehicle chargers along the highways and in communities.

II. Key Policies in California and in the ZEV Alliance States

- ZEV Mandate, which requires OEMs to sell an increasing percentage of ZEVs over the years.
- The Zero Emission Bus (ZEB) regulation, which aims for 100 percent ZEB market by 2040.
- The Advanced Clean Truck regulation, which will require an increasing percentage of the trucks sold in California to be zero emissions starting from 2024.
- The Low Carbon Fuel Standard (LCFS) is designed to decrease the carbon intensity of California’s transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives, including supporting ZEV adoption and ZEV infrastructure build-up.
- The Clean Miles Standard (CARB, 2021) sets electrification and greenhouse gas emission targets for transportation network companies such as Uber and Lyft to adopt ZEVs.
- The proposed Advanced Clean Fleets Rule will require California fleet owners and operators to purchase ZEVs.
- The Heavy-Duty Engine and Vehicle Omnibus Regulation (Omnibus Regulation) became effective on December 22, 2021, to further cut smog-forming nitrogen oxides

Figure 2 | California’s ACT Regulation: Sales Requirements for Zero-emission Trucks



Source: CARB

(NO_x) from conventional heavy-duty engines. Given that few internal combustion engine (ICE) technologies can meet the ultra-low NO_x standards, the Omnibus Regulation may encourage industry to shift more effort to the manufacture of ZEVs.

- \$10 billion multi-year ZEV and ZEV infrastructure funding (\$1.75 billion proposed for 2021-22 budget year).

III. Key Policies in China

- The Dual-credit Policy sets NEV credit quota requirements and a one-way credit exchange with the Corporate Average Fuel Consumption (CAFC) for passenger vehicles. The policy is currently the most important tool to compel OEMs to sell NEVs to the market. The most recent policy proposal (Ministry of Industry and Information Technology, 2022) aims for 24-38 percent of NEV market share to meet the NEV credit quota requirement by 2025; If we add the potential NEVs needed to comply with the CAFC standards, China's OEMs will potentially add another 10 percent¹ of NEVs to the market, making it 34-48 percent NEV market share by 2025. No doubt, in the next ten years, the Dual-credit policy is the policy tool in China, especially for passenger vehicles.
- The “Battle for the Blue Sky” initiative covers the key areas for air pollution prevention and control. Started in 2018, it is now expanded from the original 74 cities to 168 (prefecture-level and above) cities. Under this initiative, all covered cities shall reach 50% new NEV market share by 2030. In the long run, climate and environmental policies, rather than industrial policies, will be the main driver for ZEV adoption in China.
- License plate restriction policies have been adopted in several major Chinese megacities such as Shanghai, Beijing, and Shenzhen either in the form of the auction of license plates or lottery or a combination of both. In those cities, it is much easier or cheaper to buy NEVs than elsewhere. The six megacities with the vehicle restriction policy used to account for 46 percent (National Development and Reform Commission, 2017) of China's NEV market in 2015. Today, they only account for 27 percent (Carmen Digest, 2022) of the market.
- NEV purchase incentives.
 - Subsidies used to be as high as \$16,181 (Wang, Sperling, Tal, & Fang, 2017) including local subsidies and played a very important role, but China's subsidies are to be phased out at the end of 2022.
 - NEV vehicle purchase tax exemption. Car buyers are exempted from the 10 percent purchase tax over the car price, which could be substantial. The government has just extended this policy beyond 2022.

Market Readiness and Challenges

We assess ZEV market readiness with two key indicators: model availability and diversity, and cost.

For light-duty vehicles (LDVs), both countries have offered a wide variety of ZEV models that fully meet consumers' diversity needs. For commercial vehicles, however, most available models have been limited to the light and medium vehicle segments (or weight classes). Both countries need to continue to work on providing ZE heavy-duty truck (HDT) models to their markets (Figure 3).

As the battery cost takes a significant share of a complete ZEV cost, the trend of battery cost greatly affects when ZEVs meet cost parity with internal combustion engine vehicle (ICEV) counterparts. Battery pack prices have fallen by 89 percent from 2013 to \$132/kWh in 2021 (Figure 4). In China, battery pack prices are even cheaper, at \$111/kWh (Henze, 2021). In the microcar segment, BEVs, with nearly 100 percent market share, are overwhelmingly

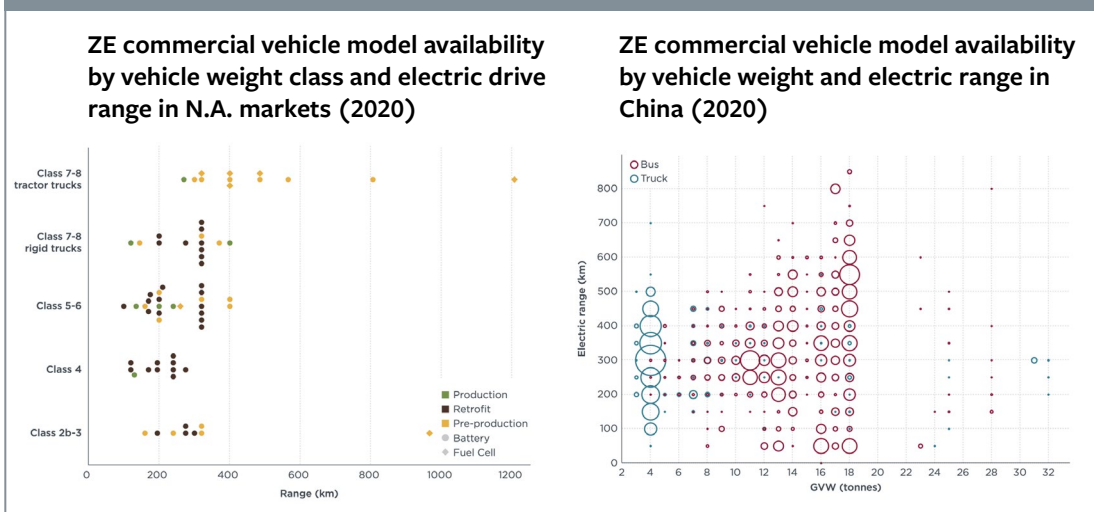
¹ In 2021, the NEV credit requirement was 14 percent, and the average range of the Chinese BEV sold that year was 392 km, which could generate 2.584 credits. As a fleet, 5.4 percent of 392 km BEV sales can meet the 14% NEV requirement. Yet, the NEV market share reached 15.5% in 2021. We can assume that the urgency to over-produce NEVs to cover the CAFC shortfalls made OEMs jointly provide 10 percent more NEVs than is needed under the NEV credit requirement (15.5% over 5.4% needed in 2021 with an average fleet range of 392 km.)

Table 1 | Directions and ZEV Targets and Law/Regulations in China and the United States

		China	The United States (Administrative Goal)	California, (U.S.)
Overall targets for low-carbon development		Strive to peak CO ₂ emissions by 2030 and achieve carbon neutrality by 2060 (PLAN)	Cut carbon emissions by 50-52% below 2005 levels in 2030; and strive to achieve net-zero carbon emissions by 2050	Reduce GHG emissions by 40% below 1990 levels in 2020 (law); GHG emissions to be 40% below 1990 levels in 2030; achieve net-zero carbon emissions by 2045
ZEV goals	Short-term	<p>NEV sales reach about 20% of all vehicle sales in 2025; with about 40% of NEV and clean energy-powered vehicle sales in the country's total motor vehicles by 2030 (PLAN)</p> <p>By 2030, NEV market share should reach 50% in the 168 cities as key areas for air pollution prevention and control (PLAN)</p> <p>Hainan Province has committed to reaching 100% NEVs market by 2030 (PLAN)</p>	In 2030, half of all new vehicles sold are to be ZEV, including battery electric vehicles (BEV), plug-in hybrid vehicles, and hydrogen fuel cell electric vehicles.	<p>Percentage of ZEV in total bus sales (LAW)</p> <p>2023:25%; 2026:50%; 2029:100%</p> <p>Truck sales at different classes: 50/70/40% of sales are ZEVs in 2035 (LAW)</p>
	Medium- and long-term	In 2035, BEV will become the mainstream of new vehicles sold, and the public transport will be fully electrified.	In 2050, electric and biofuel-powered vehicles will become the mainstream of transport.	<p>100% sales of light-duty vehicles are to be ZEV in 2035 (law)</p> <p>Transition to all-electric public bus fleet in 2040 (law)</p> <p>100% of medium- and heavy-duty trucks sold are to be ZEV in 2045.</p>
	Infrastructure	More than 10 million charging contacts (in 2025) in the country based on provincial 14th five-year plan (2.6 million charging contacts at the end 2021) (PLAN)	<p>Charging station every 50 miles on Alt Fuel Corridors (a 190,000-mile network), within 1 mile of the freeway</p> <p>Minimum of four 150 kW chargers with 600 kW capacity</p>	<p>By 2025, build 200 hydrogen refueling stations, 250,000 charging piles, including 10,000 fast chargers</p> <p>1.2 million public and shared chargers for LDVs and 157,000 chargers for HMDVs by 2030</p>

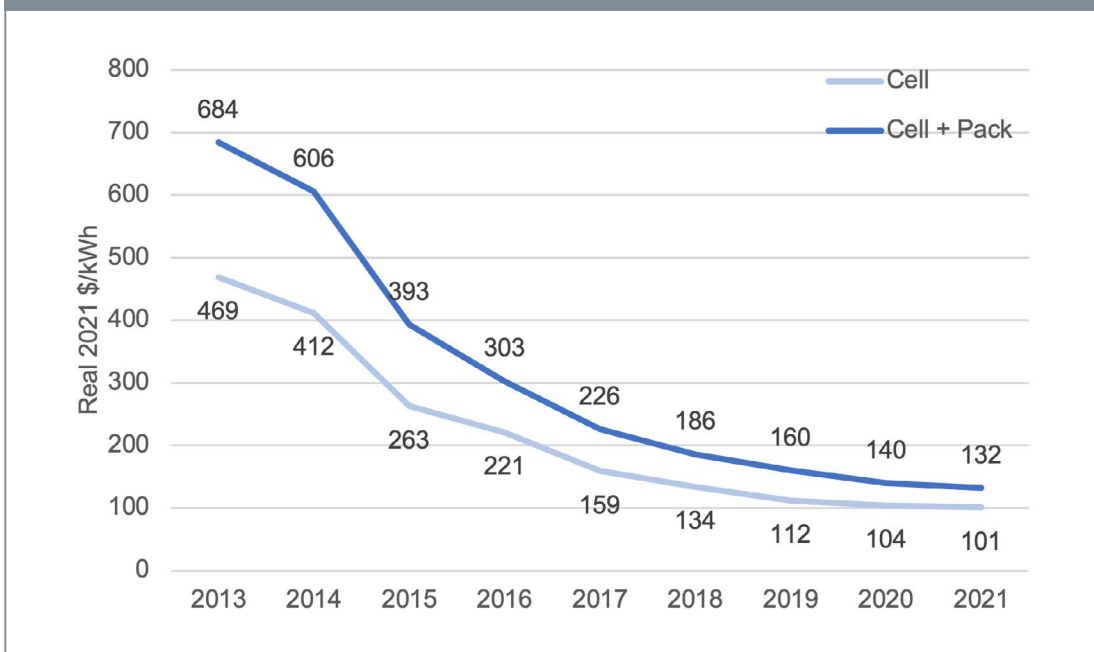
Source: EV100, CARB, and media reports.

Figure 3 | ZEV Market Readiness



Source: ICCT

Figure 4 | Volume-weighted average pack and cell price split



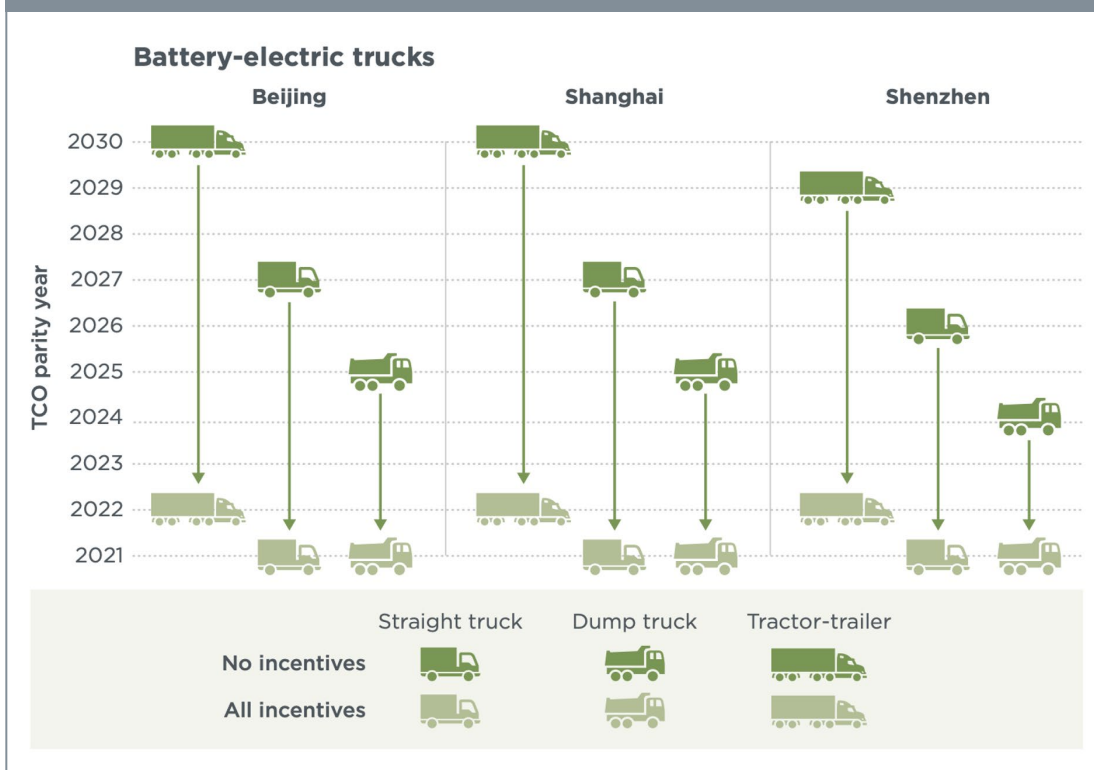
Source: BloombergNEF

competitive both in total cost of ownership (TCO) and in purchase price, and this encouraging trend is expanding to larger passenger vehicle segments as gasoline price soars in China.

ZE passenger cars are approaching cost-parity, in terms of the total cost of ownership (TCO), in both the U.S. and China. The ICCT estimated that electric car initial price parity is likely to be achieved around 2025-2030 in China, with shorter-range electric cars hitting the price-parity points earlier. The TCO parity for electric car buyers in China will be reached several years earlier than vehicle purchase price parity, based primarily on electric vehicles' fuel savings. In further consideration of the full vehicle lifetime effects through a broad transition to 90% new electric vehicle sales by 2035, larger cost savings can be experienced widely across drivers in China (Lutsey, Cui, & Yu, 2021).

Even for the harder-to-electrify heavy-duty vehicle segments like heavy dump trucks and semi-tractor trucks, the ICCT estimated that the cost parity can be reached before 2030 in representative Chinese cities (Figure 5).

Figure 5 | TCO parity years for ZV trucks with and without policy incentives in typical Chinese cities



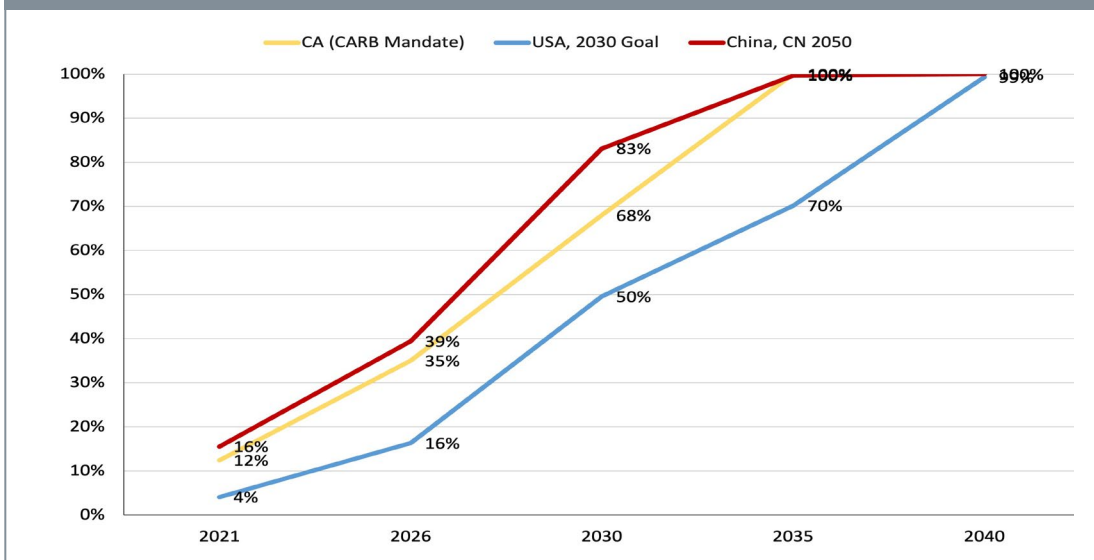
Source: ICCT

Even if TCO and purchase price parities are reached for ZEVs in China and the U.S., the market alone cannot accelerate the high penetration rate needed for both the United States and China to reach carbon neutrality in 2050 and 2060, respectively. With LDV fleet replacement usually taking 15-20 years to complete, 100 percent ZEV sales need to happen as early as 2035 in the United States. In China, if the 2060 carbon neutrality target is for the whole transportation sector, then road transportation should reach carbon neutrality by 2050, leaving some room for China’s rapidly expanding aviation and shipping sectors to decarbonize their transportation fuels. This means China should reach 100 percent ZEV deployment somewhere between 2035 and 2040 (Figure 6).

CARBON REDUCTION POTENTIAL

In the U.S., on-road vehicles emitted 1,377.6 Tg CO₂ Equivalent of GHG Emissions or 22.1 percent of the total GHG emissions in the United States in 2020 (US EPA, 2022). The United States is committed, and President Biden has set a goal to reduce net greenhouse gas emissions by 50% in 2030 and that half of all new light-duty cars sold in 2030 to be ZEVs (The White House, 2021a, 2021b). These goals, even if codified in law, still need considerably more initiative to achieve the U.S. commitment to reach carbon neutrality before 2050, including road transportation. A recent report demonstrated that, with the right policy and rapid reduction in the total cost of owning and operating EVs, it is technically and economically feasible for all new car and truck sales to be electric by 2035 (Goldman School of Public Policy, UC Berkeley, 2021). This means the ZEV market share in LDVs should increase by 31% per annum from now to 2030. The report estimates that the TCO parity will be reached for LDVs in 2023 and for Heavy duty trucks (HDTs) has already been achieved. The potential of a 100 percent ZEV market is here, waiting for the policy to be finalized. A previous study by a UC Davis team (Chakraborty, Buch, & Tal, 2021) concluded that TCO is not a single number. LDV TCO varies across market segments due to heterogeneity in annual miles traveled, differences in access to home charging, the cost of electricity, and vehicle preference based on household fleet composition. However, cost parity will be achieved between the years 2025 and 2030 by all household categories.

Figure 6 | Stated and Expected LDV ZEV Growth to Reach 100 Percent Sales



Note: China 2021-2030 trajectory is based on the UC Davis China 2050 Scenario. 2030-2035 is what is expected but a very plausible growth trend. The U.S. 2030-2040 growth trend is what is expected and most plausible. The urgency is to reach 100 percent ZEV sales around 2035 to guarantee carbon neutrality in road transportation by 2045.

A team of researchers from UC Berkeley, UC Davis, UC Irvine, and UCLA, conducted a study to provide a research-driven analysis of possible policy options that could, if combined, put the state on the pathway to a carbon-neutral transportation system by 2045. In its High ZEV scenario, the study found that to reach 100 percent ZEV sales in light-duty vehicles in 2035, ZEV sales should reach around 60-70% by 2030, assuming that there is a rapid reduction in vehicle-mile traveled (Brown et al., 2021). This implies that the ZEV market share in LDVs should increase by 21.5% per annum from now to 2030.

Accordingly, in response to Governor Newsom’s executive order, the CARB raised the ZEV mandate to 35 percent of new sales for 2026, 68 percent in 2030, and 100 percent in 2035 (Table 2). Although the mandatory market penetration rates are raised in a linear fashion, we believe that the real market-based compliance will grow faster, most likely in an S shape.

Table 2 | California requires automakers to deliver more Zero Emission LDVs 2026-2035

Model Year	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ZEV & PHEV percentage	35%	43%	51%	59%	68%	76%	82%	88%	94%	100%

Note: Automakers will be allowed to meet no more than 20% of their ZEV overall requirement with PHEVs.

In China, it is estimated that the transportation sector emits about 10-14% of the nation’s GHG emissions. An ICCT study suggests that without further policy interventions, transportation related GHG emissions may increase by 45% in 2050 (Jin et al., 2021).

UC Davis China Center for Energy and Transportation (C-CET) estimated that under the current Stated Policy Scenario, China’s automotive sector will only reach carbon peaking in 2040 vs. 2030 under the China 2050 Scenario. By 2050, the automotive sector’s GHG emissions will be three times above 2010 level vs. a reduction to 39 percent of 2010 level under the China 2050 Scenario. There is an urgency to accelerate China’s NEV deployment (Figure 7).

Based on the same study, the UC Davis team estimated how the road transportation sector to reach carbon neutrality before 2050. Under the China 2050 Scenario, China should reach LDV NEV market share of 76 percent in 2030, 98 percent in 2035, and 100 percent in 2040; whereas in the

Figure 7 | GHG Emissions between the Stated Policy (BAU) and the China 2050 Scenario

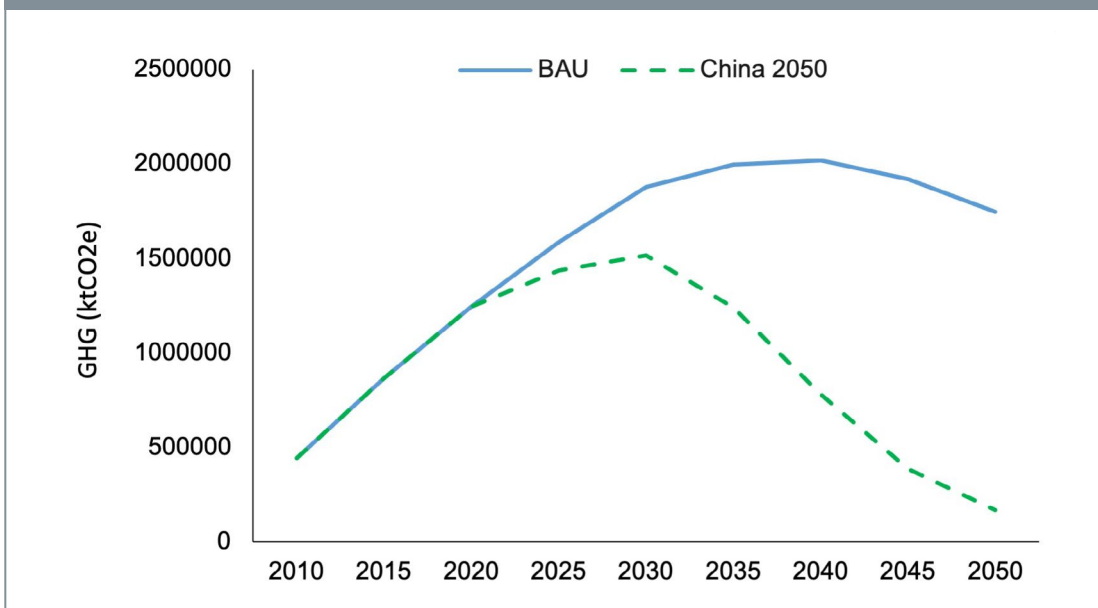
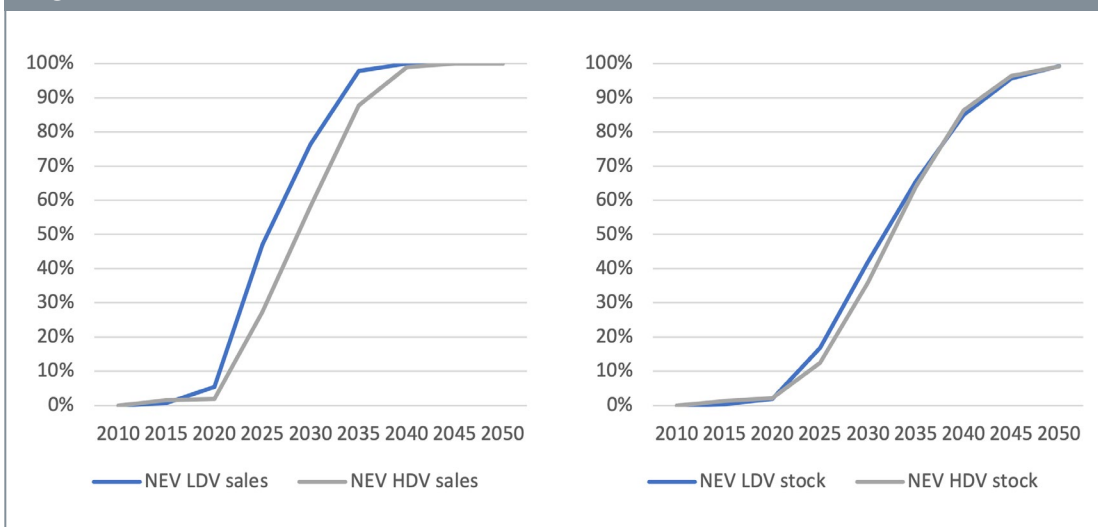


Figure 8 | NE-LDVs and NE-HDV Sales and Total Stock under the China 2050 Scenario



Note: With an overall shorter lifetime, the HDVs turn around faster than the LDVs.

commercial vehicle subsector, NEV market share should reach 58 percent in 2030, 88 percent in 2035, and 99 percent in 2040 or before. The whole vehicle stock will be NEVs in 2050 (Figure 8). Urban transit buses and delivery vehicles are the low-hanging fruits among commercial vehicles. The Chinese city Shenzhen reached 100 percent EV transit bus fleet operation in January 2019 (China Business Daily, 2019) and now has 860,000 electrified urban logistic vehicles on road (Shenzhen Ecological Environment Bureau, 2021). Nationwide, NEV transit buses already reached 93 percent of the total market share in 2019 (CATS 2020) and are expected to reach 100% soon. NEV Urban logistics vehicles are not far behind.

RECOMMENDATIONS FOR THE U.S.

As recommended in the America’s Zero Carbon Action Plan (Sperling, Fulton, & Arroyo, 2020), the key elements of policy should include 1) long-term binding rules requiring or motivating automakers to electrify their vehicles; 2) incentives for buyers in the near- and mid-term that improve equity; 3) public investment in charging infrastructure, with a focus on multi-family

dwelling and public charging; 4) increased outreach, education, and engagement; and 5) local leadership by cities and regions in support of these aforementioned policies. Specifically:

1. ZEV sales mandates are the number one effective policy for decarbonizing transportation. The U.S. should follow California and the ZEV alliance states to require automakers to sell an increasing percentage of ZEVs. The mandate provides a long-term policy and market signal to OEMs that they will need to invest in ZEV manufacturing to stay competitive. We recommend a National LDV ZEV mandate at a minimum of 50 percent of new sales by 2030 and 100 percent of new sales by 2040; and a National Heavy and Medium Duty (HMD) ZEV mandate to reach 80-100 percent of new sales in 2050.
2. GHG and/or fuel economy performance standards need to be tightened at least 5 percent per year. If the loophole of the different standards for trucks is closed, a tightened GHG policy can replace the ZEV mandate, as is happening in Europe. GHG standards can be developed to incorporate the full lifecycle of the vehicles, encouraging more efficient and circular manufacturing.
3. Reducing per capita vehicle use by incentivizing services that include conventional buses and rail, pooled ride-hailing services, and bicycles, e-bikes, and e-scooters. A mandatory policy for automated vehicles to be electrified and shared-in-use will be helpful.
4. National low-carbon fuel standards covering all fuels for road vehicles and airplanes will support ZEV adoptions through credits sold by ZEV automakers and low-carbon fuel/electricity providers, and will reduce the carbon footprint of the liquid fuels needed to fuel legacy ICEVs.
5. Rapid buildout of ZEV refueling infrastructure that supports vehicle-grid integration and is consumer-friendly and future-proofed.

RECOMMENDATIONS FOR CHINA

In the next 12 months:

- a) Adopt the NEV sales mandate for commercial vehicles as early as possible to accelerate ZEV deployment and nurture innovative ZEV automakers.
- b) Raise 2025 NEV market share target from around 20 percent to 28-30 percent so that automakers will have a future target to look forward to.
- c) Extend some subsidies for the purchase of NE HD trucks, but not for NE LDVs. The NE HD truck's market share was only 0.9 percent in 2021 (Ye & Mao, 2022).

In the 2020s:

2. Extend both ZEV mandates to ten years or longer, as California does, with technology-neutral sales requirements matching those of the carbon neutrality targets. The mandates will provide a long-term policy and market signal to OEMs that they will need to invest in ZEV manufacturing to stay competitive. Establish a National LDV ZEV mandate at a minimum of 70-80 percent of new car sales by 2030 and 95-100 percent of new car sales by 2035. Enact a National HMD ZEV mandate to reach 56 percent in 2030, 100 percent of new sales before 2040.
3. Develop and adopt enforceable vehicle regulations and central policies to collectively drive the ZEV vehicle market growth. The policy package shall include: world-class vehicle emissions regulations that require 90% of NOx emission reduction for new HDVs, 100% CO₂ emission reduction for passenger cars, and 70% CO₂ emission reduction for mid- and heavy commercial vehicles by 2035. Corporate Average Fuel Consumption (CAFC) standards should be further tightened after 2030, perhaps with another 20 percent efficiency improvement to reach 2.56 L/100 km in 2035. Eventually CAFC could be replaced by the GHG standards on vehicles to incorporate the full lifecycle of the vehicles. Enforcement of standards should be strengthened accordingly.

4. A special multi-ministry group should be formed, coordinated by the Ministry of Ecology and Environment (MEE) to adopt China's GHG regulation on vehicles to meet the 2050 or 2060 carbon neutrality goal in road transportation in support of China's commitment to reach carbon neutrality in all sectors, including the ever-expanding transportation sector.
5. Internalize the hidden cost of oil supply insecurity and damages to environment and public health to keep the gasoline and diesel prices high even after global oil price comes down. High fuel cost makes NEVs more attractive. This could also be replaced by a feebate system, a revenue-neutral rebate for EVs paid by a fee on high GHG emitting vehicles.
6. Introduce low carbon fuel standards in pilot regions to generate innovations in low-carbon biofuels and indirectly support ZEV deployment through credits generated by ZEV automakers.
7. Rapid buildout of ZEV refueling infrastructure that supports vehicle-grid integration and is consumer-friendly and future-proofed.
8. Reducing per capita vehicle use by incentivizing services that include conventional buses and rail, pooled ride-hailing services, and bicycles, e-bikes, and e-scooters. Differentiate public transit needs between densely populated megacities and third and fourth tier cities. A mandatory policy for automated vehicles to be electrified and shared-in-use will be helpful.
9. Develop ambitious subnational ZEV targets, following the Hainan model. Select volunteer provinces (Hainan) and cities (Shenzhen) as pilots to reach 100 percent NEVs in the fleet for 3 purposes:
 - a) Set up models for others to follow.
 - b) Understand the cost and benefit of a 100 percent NEV fleet economy.
 - c) Identify best practices and lessons worth learning.

RECOMMENDATIONS FOR BOTH COUNTRIES TO COLLABORATE

Communicate, exchange, and collaborate on developing ZEV requirements for cars and trucks as well as the next phase of national vehicle emission regulations to further stimulate the ZEV model offering and market development. Communicate, exchange, and collaborate on subnational policies and activities.

1. Exchange of policies and best practices, especially in HMD trucks. California has already adopted the ACT regulation. China is developing a similar ZEV mandate for commercial vehicles. The two sides should continue to engage each other and share policy adoption and implementation experiences with each other. Given the encouraging results of the Dual-credit Policy, we believe that the Chinese ZEV mandate for trucks will have an equal or greater impact on its zero-emission truck adoption.

On the business and technology side, the battery-swap HD (BSHD) truck segment is growing rapidly in China. Currently close to half of the 10,120 new energy HD trucks sold in the first half of the year are battery-swap HD trucks (China Automs, 2022), increasing by a factor of 15 over the same period last year. BSHD trucks are the driving force behind China's accelerated adoption of ZEVs in HD trucks. There is no BS truck sold in the United States. Given California's target of a full ZEV fleet in trucks by 2045, it's highly recommended that California explores a demonstration of BSHD trucks as the state is in the process of locking in the investment of expensive high-voltage charging stations and hydrogen stations.

2. Full cell electric vehicles (FCEVs) may still take a 5-20 percent of the market share both in passenger vehicles and HMD trucks, given the fact that large countries like China and the United States will need to diversify their energy supply mix away from a single source, electricity or liquid.

Densely populated Chinese cities are beginning to run out of fixed parking spaces. In addition to fast chargers, FCEVs may still provide a badly needed service with its advantages in quick refueling and a longer range. Presently, there is a theoretical advantage for FC HD trucks, since they can travel long distances without adding heavy loads and experiencing at least 30/60-minute charging time every 200-300 miles traveled. FCEV adoption is slowing down in California, but in China, a cluster of cities are demonstrating FCEVs with strong government support. In the first half of 2022, about 1,400 FCEVs were sold in China, mostly HD trucks, transit buses, and special vehicles. The U.S. should work with China in harmonizing hydrogen refueling standards, and both countries should open their markets for FCEVs to further bring down the price of fuel cell stacks.

3. Vehicle to grid integration is a new area and will play an increasingly important role in the interaction between the vehicle as bidirectional energy storage and the grid as the conduit for intermittent renewable energy. The two countries can share the best practices and lessons learned for mutual benefit.
4. Both countries should work to develop an internationally harmonized and standardized carbon emissions accounting and evaluation system with a database for the transportation industry. The two countries should explore ways to set and improve lifecycle carbon emission standards for the manufacturing of vehicles and powertrain products, batteries or fuel-cell stacks.
5. Keep investing in developing both high-end technologies such as solid-state batteries with very high charging speed and power performance and lower cost technologies that will cover all market needs. Keep technology neutral as possible.

ANNEX 1

ZEV Policy Participants in China

Many of the Chinese NEV policies and plans have to be cleared by the State Council, but usually in the form of a joint policy among several ministries. The State Council issued the New Energy Vehicle Industry Development Plan (2021-2035), which provides the long-term guideline for NEV development in China.

The Ministry of Industry and Information Technology (MIIT) is the main sponsor of the Dual-credit Policy and it's also responsible for the upcoming NEV policy for commercial vehicles.

The Ministry of Ecology and Environment (MEE) has been increasingly engaging in ZEV adoption either through its stringent vehicle emission standards or its requirement for the 168 cities under the "Blue Sky" initiative.

The National Development Reform Commission (NDRC) is in charge of planning. It provides permits for the building or expansion of new vehicle factories.

The Ministry of Finance (MOF) used to be among the most important ministries because it provides much-needed subsidies and vehicle purchase tax exemptions. Now that the subsidies are phasing out, the tax exemption has become the sole incentive tool for the MOF.

The Ministry of Science and Technology once played a crucial role in China's emergence as a ZEV superpower through the massive demonstration program, but now its focus is on the hydrogen and fuel cell EV demonstration and other key technology innovations.

Several government or non-government organizations play an advisory role:

- China's EV100 is a platform for OEMs, battery makers, academics, and government officials. It provides policy proposals to the government.
- SAE-China now takes a role in long term technology development in the automotive sector.

It has completed the Vehicle Technology Road Map version 1 and version 2. Many of the recommendations in the Road Maps eventually ended up in the government targets.

- The Chinese Association of Automotive Manufacturers is a trade group that provides feedback to the proposed government policies. Because of its membership fee structure, its advice tends to reflect large automakers.
- Chinese Automotive Research and Technology Center Co. Ltd. sends its employees to work in the automotive sections of several ministries. It also drafts the Dual-credit Policy and other policies for the government while conveying feedback from OEMs. When there are major issues such as massive cheating on the EV subsidies or major battery accidents, the government usually sends CATARC researchers and engineers to the field to investigate and provide their analyses and recommendations.
- The Vehicle Emission Control Center of the MEE sets vehicle emission standards for LDVs and HMD trucks. They will play an increasingly important role as China may eventually move toward using GHG as regulations on vehicles.

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