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THE GLOBAL AUTOMAKER RATING 2023

Who is leading the transition to electric vehicles?

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ABOUT THE ICCT AND THIS REPORT

The ICCT is an independent, nonprofit organization that provides first-rate, unbiased research and policy analysis on clean transportation to government officials and other relevant stakeholders from civil society and industry. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation to benefit public health and mitigate climate change. The ICCT is the world's leading research organization dedicated solely to clean fuel and vehicle policies and the decarbonization of the transport sector by mid-century.

While the ICCT typically supports government policymakers and regulators as they develop policies to reduce transportation emissions, this report is for a wider audience. We believe the same approach we use to support government regulations—that is, providing timely, high-quality data and analysis to decision-makers—can help inform investors, the broader financial sector, consumers, and auto companies at this critical time in the industry.

This report compares global automakers in the transition to zero-emission vehicles. Our assessment might be of value to investors and rating companies. Consumers may also be interested in knowing how much effort each automaker is making to transition to a fully decarbonized vehicle market and supply chains. And auto companies themselves, all of which have pledged to achieve carbon neutrality, might find our data-driven, transparent assessment of their actions and plans to be a valuable yardstick as they work to find opportunities to improve.

DISCLAIMER

This ICCT report is intended for informational purposes only. Although the ICCT has endeavored to organize and present data from multiple third-party sources in an even-handed and neutral fashion, the selection, interpretation, weighting, and presentation of the metrics in this rating reflect the subjective assessments and opinions of the ICCT. Additionally, while the ICCT has only used data sources it believes to be reliable, taken steps to verify such data with automakers, and identified its sources in the interest of transparency and verification, it cannot state that the data compiled and published by others is accurate. This report should not be construed otherwise.

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EXECUTIVE SUMMARY

Automakers around the world will need to rapidly transition to zero-emission vehicles (ZEVs) in the next decade to put the industry on track to meet the climate goals in the Paris Agreement. Overall, the ZEV industry continues to show strong growth, with a 40% increase in ZEV sales from 2022 to 2023 across the 21 major companies considered in this report. Ambitious technology-forcing regulations adopted by the European Union, United States, Canada, and the United Kingdom in 2023 and early 2024 are expected to further accelerate the ZEV transition over the coming years.

This report updates the *Global Automaker Rating 2022* report and assesses how the world's largest automakers stack up in the transition to ZEVs—that is, battery electric vehicles (BEVs) and fuel-cell electric vehicles (FCEVs). Focused on the top 21 light-duty vehicle manufacturers in the world by sales in 2023, we use the same 10 custom-built metrics as in the 2022 report to reflect automakers' efforts and strategies in transitioning their vehicle fleets to zero tailpipe emissions and decarbonizing production processes. We refined the evaluation methodologies of selected metrics to better capture the year-on-year movement across manufacturers. Nevertheless, the consistency in our evaluation framework enables us to track automakers' progress from 2022 to 2023. Figure ES1 compares our 2022 ratings (numerical scores) with our 2023 findings.

From 2022 to 2023, the numerical scores of seven automakers increased, 12 decreased, and one stayed the same. As ratings are based on relative performance among automakers, a decrease could either mean a manufacturer's performance regressed or the performance of competitors improved. Overall, the global ZEV market advanced substantially in 2023 with growing sales, improved technology performance, and more ambitious visions.

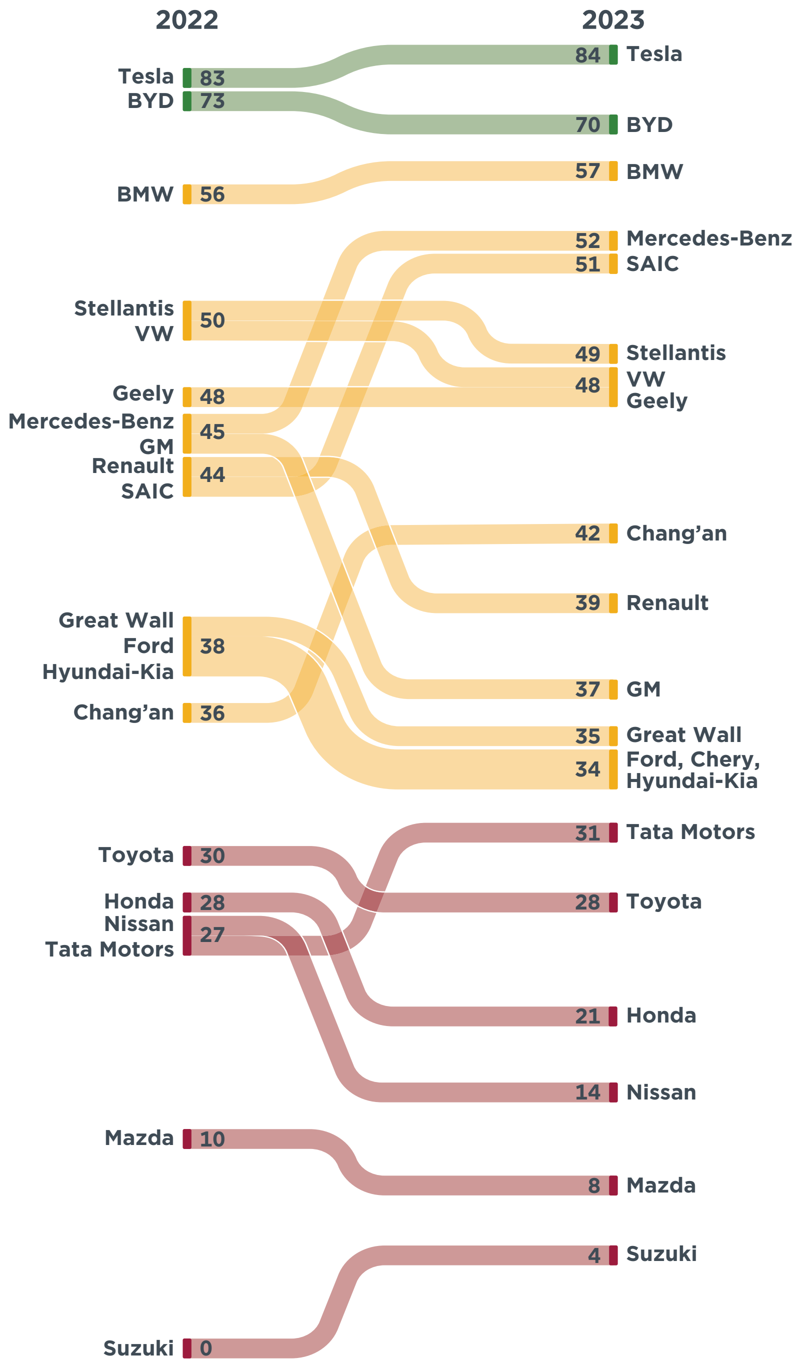
Tesla and BYD continued to lead the pack of global manufacturers in the ZEV transition. Both manufacturers already produce only electric vehicles but their future places at the top are not necessarily secure. Looking ahead, BYD will need to shift its 48% sales share of plug-in hybrid electric vehicles (PHEVs) to full ZEVs and improve the performance of its BEVs. Both Tesla and BYD will also need to introduce new models across the passenger vehicle class spectrum.

Mercedes-Benz, SAIC, and Chang'an were the most improved manufacturers in the rating compared with 2022. Mercedes-Benz was one of the most improved in decarbonizing its supply chain, with increased use of renewable energy and deployment of battery recycling and repurposing; the other was Chang'an, which announced new battery recycling and reuse efforts. SAIC grew its ZEV-equivalent sales share—the cumulative sales share of BEVs, FCEVs, and PHEVs discounted by the share of their real-world driving that uses gasoline—by 9 percentage points, more than any other automaker, and reached 40% in 2023. SAIC also made notable improvements in ZEV performance.

Automakers based in Japan and India are still at the bottom of our rating, but Tata Motors and Suzuki have shown progress. Tata Motors increased its ZEV target ambition and ZEV investment and made substantial technology improvements (e.g., in energy consumption and driving range). Suzuki, which earned a 0 rating in 2022, inched up by making progress on its ZEV strategy. Toyota, Honda, Nissan, and Mazda remained at 1%–5% ZEV-equivalent sales, and all need to catch up on diversifying their ZEV offerings and increasing ZEV investment.

Table ES1 presents the full ratings of the 21 manufacturers in 2023 and identifies changes in score from 2022. We group our 10 metrics into three pillars: market dominance, technology performance, and strategic vision. The metrics are weighted equally within each pillar and a simple average of the three pillars is used to generate the overall rating for each manufacturer. The automakers are listed in order from highest to lowest scoring. "Leaders," shown in green, scored in the top third of the rating (66.7–100). "Transitioners," in yellow, scored in the middle third (33.4–66.6). "Laggards," in red, scored in the bottom third (0–33.3).

Figure ES1
2022 versus 2023 Global Automaker Rating.



*The figure is not drawn to scale.

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Table ES1

Overall scores, Global Automaker Rating 2023.

OEM		2023 overall	MARKET DOMINANCE		TECHNOLOGY PERFORMANCE					STRATEGIC VISION		
			ZEVe sales share	ZEV class coverage	Energy consumption	Charging speed	Driving range	Renewable energy	Battery recycle/ repurpose	ZEV target	ZEV investment	Executive compensation
Tesla	LEADERS	84 ▲	100	46 ▲	94 ▼	100	100	0	100	100	100	100
BYD	LEADERS	70 ▼	76 ▲	77 ▼	69 ▼	25 ▼	64 ▼	0	100	76 ▲	68 ▼	100
BMW	TRANSITIONERS	57 ▲	17 ▲	55 ▲	73 ▲	54 ▲	90 ▲	100	93 ▲	84 ▲	17 ▼	60 ▼
Mercedes-Benz	TRANSITIONERS	52 ▲	15 ▲	50 ▼	50 ▼	43 ▲	82 ▲	100 ▲	93 ▲	90 ▼	42 ▲	15 ▲
SAIC	TRANSITIONERS	51 ▲	40 ▲	100	56 ▲	13 ▲	26 ▲	0	83 ▼	73 ▲	65 ▼	0
Stellantis	TRANSITIONERS	49 ▼	9 ▲	68 ▼	31 ▲	31 ▼	35 ▲	0	99 ▲	100 ▲	7 ▼	100
VW	TRANSITIONERS	48 ▼	11 ▲	59 ▼	61 ▲	50 ▼	87 ▲	73 ▼	97 ▲	79 ▲	22 ▼	8 ▼
Geely	TRANSITIONERS	48	29 ▲	78 ▼	37 ▼	35 ▲	51 ▼	7 ▼	98 ▼	87 ▲	45 ▼	4 ▲
Chang'an	TRANSITIONERS	42 ▲	21 ▲	93 ▲	39 ▼	5 ▲	21 ▲	0	100 ▲	73 ▲	36 ▼	0
Renault	TRANSITIONERS	39 ▼	10 ▼	74 ▼	41 ▼	15 ▲	27 ▼	0	95 ▲	84 ▼	11 ▼	24 ▼
GM	TRANSITIONERS	37 ▼	4 ▲	19 ▼	59 ▲	29 ▼	75 ▼	0	74 ▼	87 ▼	10 ▼	55 ▼
Great Wall	TRANSITIONERS	35 ▼	17 ▲	46 ▼	46 ▼	18 ▲	53 ▲	0	100	89 ▼	3 ▼	0
Ford	TRANSITIONERS	34 ▼	4	30 ▲	23 ▼	48 ▼	86 ▼	14	92 ▲	79 ▼	11 ▼	11 ▲
Chery	TRANSITIONERS	34	17	78	46	4	4	0	100	58	17	0
Hyundai-Kia	TRANSITIONERS	34 ▼	7 ▼	30 ▼	26 ▼	79 ▲	71 ▼	11	100	54 ▲	21 ▲	0
Tata Motors	LAGGARDS	31 ▲	8 ▲	23 ▼	100 ▲	5 ▲	42 ▲	7 ▲	81 ▼	71 ▲	20 ▲	4 ▲
Toyota	LAGGARDS	28 ▼	2 ▲	28 ▼	71 ▲	32 ▼	82 ▲	6	59	48 ▲	9 ▲	0
Honda	LAGGARDS	21 ▼	1 ▲	6 ▼	35 ▼	26	54 ▲	0	42 ▲	67 ▼	19 ▼	0
Nissan	LAGGARDS	14 ▼	5 ▲	28 ▼	18 ▼	22 ▲	30 ▲	0	33 ▲	0 ▼	9 ▼	5 ▼
Mazda	LAGGARDS	8 ▼	2 ▲	3 ▼	0	19	2 ▼	0	0	38 ▲	15 ▼	0
Suzuki	LAGGARDS	4 ▲	0	0	N/A	N/A	N/A	0	0	32 ▲	4 ▲	0

Note: ▲ indicates score increase compared with 2022; ▼ indicates score decrease compared with 2022.

Our metrics reveal some notable trends across manufacturers.

Most automakers improved their performance across six metrics: ZEV sales shares, energy consumption, driving range, ZEV target, ZEV investment, and executive compensation. Because the top performers set new benchmarks for some metrics, not all automakers that improved their performance saw a score increase for a given metric. Fifteen automakers increased their **ZEV-equivalent sales share**, which increased to 15% on average across all automakers, up from 11% in 2022. China-based automakers (BYD, SAIC, Geely, Chang'an, Great Wall, and Chery) had some of the highest ZEV-equivalent sales shares.

Eleven automakers made their BEVs more efficient by reducing average **energy consumption**. Of these, however, only seven saw a score increase relative to their competition because Tata Motors set a new benchmark, bumping Tesla out of the top spot. On average, the energy consumption of BEVs across automakers fell by almost 4%, from 140 Wh/km in 2022 to 135 Wh/km in 2023, showing technological progress across the industry. Fourteen automakers increased the average **driving range** of their BEVs, an important performance metric for consumers; five of them (SAIC, Great Wall, BMW, Tata Motors, and Toyota) increased by more than 50 km. Across all the manufacturers, the average BEV driving range increased from 395 km in 2022 to 419 km in 2023.

Seven automakers publicly increased their **ZEV targets**. Five of them (Geely, SAIC, VW, Hyundai-Kia, and Tata Motors) increased targets for at least some of their brands by 5–20 percentage points. Suzuki announced its first ever ZEV target, while BMW moved its 100% ZEV target for MINI from the early 2030s to a clearly indicated target year of 2031. Thirteen automakers were **investing more in the ZEV transition** compared with the 2022 rating. Tesla still led in investment with $3,740 per vehicle. Meanwhile, seven automakers either introduced or strengthened linkages between top **executives' compensation packages** and ZEVs or vehicle CO_2. A greater share of executive pay at Stellantis, BMW, and GM was linked to EV deployment in 2023 compared with 2022. Ford and Mercedes-Benz tied their executive compensation packages to EVs for the first time in 2023, while Volvo Car (owned by Geely) and Jaguar Land Rover (owned by Tata Motors) added a CO_2 emissions element to their compensation rubrics. This trend shows that success in the ZEV transition is increasingly seen as critical to the future financial viability of the automotive industry.

Automakers continued to struggle with ZEV class coverage. Overall, total ZEV model offerings increased by between 10% and 42% across the six markets surveyed. But that trend was uneven across automakers in terms of the variety of ZEV models offered: seven manufacturers discontinued certain ZEV models, resulting in no ZEV option in corresponding segments in 2023. For our 2023 rating, we made a change to our class coverage assessment to give automakers credit for offering vehicle classes only in markets in which more than 1,000 of those vehicles were sold. This led to a decline in scores for several automakers. Some automakers faced score declines because they only sold some ZEV models in selected markets, while others saw dwindling sales of vehicle models that have since been discontinued.

The purpose of this rating is to explore which automakers are leading in the ZEV transition. There are other actions automakers can take to support the transition that cannot be captured by the data-driven approach in this rating but are nonetheless important. This includes support for enhanced regulation, such as Ford and GM's backing of the U.S. Environmental Protection Agency (EPA)'s light-duty vehicle standards, which EPA projects will lead to 68% ZEV and PHEV sales by 2032 in the United States. Actions like this demonstrate a commitment to the ZEV transition.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Transitioning the auto industry away from internal combustion engine vehicles (ICEVs) to zero-emission vehicles (ZEVs), including battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs), is critical to meeting the goals set in the Paris Agreement. By our estimate, ZEV sales among new light-duty vehicles (LDVs) in major global markets will need to reach an interim target of 77% in 2030 and almost 100% by 2035 to align with a below 2 °C climate trajectory (Sen & Miller, 2022).

In 2023, several governments strengthened policies to support the ZEV transition in the LDV segment. Canada adopted ZEV regulations that require 100% electric vehicle (EV) sales, including ZEVs and plug-in hybrid electric vehicles (PHEVs) by 2035; the European Union adopted carbon dioxide (CO_2) emission standards with a fleet average target of 0 g/km by 2035; and the United Kingdom adopted ZEV regulations that require 80% ZEVs among new car sales by 2030 and proposed 100% ZEV sales by 2035. In early 2024, the United States adopted greenhouse gas (GHG) emission standards that, by U.S. Environmental Protection Agency (EPA) estimates, will lead to EVs being 68% of new LDV sales by 2032. As governments continue making policies to move the industry closer to meeting climate goals, automakers around the world will need to rapidly transition to ZEVs.

This changing reality continues to be reflected in new vehicle sales and automakers' ambitions. The share of EVs has been growing rapidly in leading markets. In 2023, the EV share of new LDV sales—including cars, vans, and light commercial vehicles such as pick-up trucks—reached 33% in China, 21% in Europe, and 9% in the United States. Vehicles sold by automakers that set targets to phase out the production of ICEVs accounted for 46% of LDV sales in 2023. As the sector proceeds toward majority EV shares for new car, van, and pickup truck sales, the companies that successfully navigate the transition are expected to be best positioned for success in a decarbonized future.

Last year, the ICCT published the first *Global Automaker Rating,* which assessed the world's top 20 automakers by sales in 2022 in the context of the global vehicle market's transition to ZEVs. This report updates that rating with data and information collected for 2023. To enable year-on-year comparisons, we follow the same evaluation framework established in the previous study. In this report, we assess the world's top 21 automakers by sales; Chery has been newly added as it ranked 18th in global LDV sales in 2023 after a big sales increase.

We use the same 10 custom-built metrics to identify and evaluate efforts by automakers to decarbonize their vehicle fleets and manufacturing operations consistent with limiting global warming to below 2 °C. As key indicators of automakers' commitments, we examine each manufacturer's latest ZEV sales and technology, actions to reduce manufacturing emissions, and overall ZEV strategies. For this report, we refined the evaluation methodologies of four of our metrics to better reflect nuances in how automakers are changing over time, including as it pertains to ZEV class coverage, ZEV target, ZEV investment, and executive compensation alignment. The sections below explain in detail all our methodologies and how they may have changed compared with the previous report. Additionally, we compare the 2023 and 2022 results for each manufacturer to provide insights into industry trends and differences in automaker strategies over time.

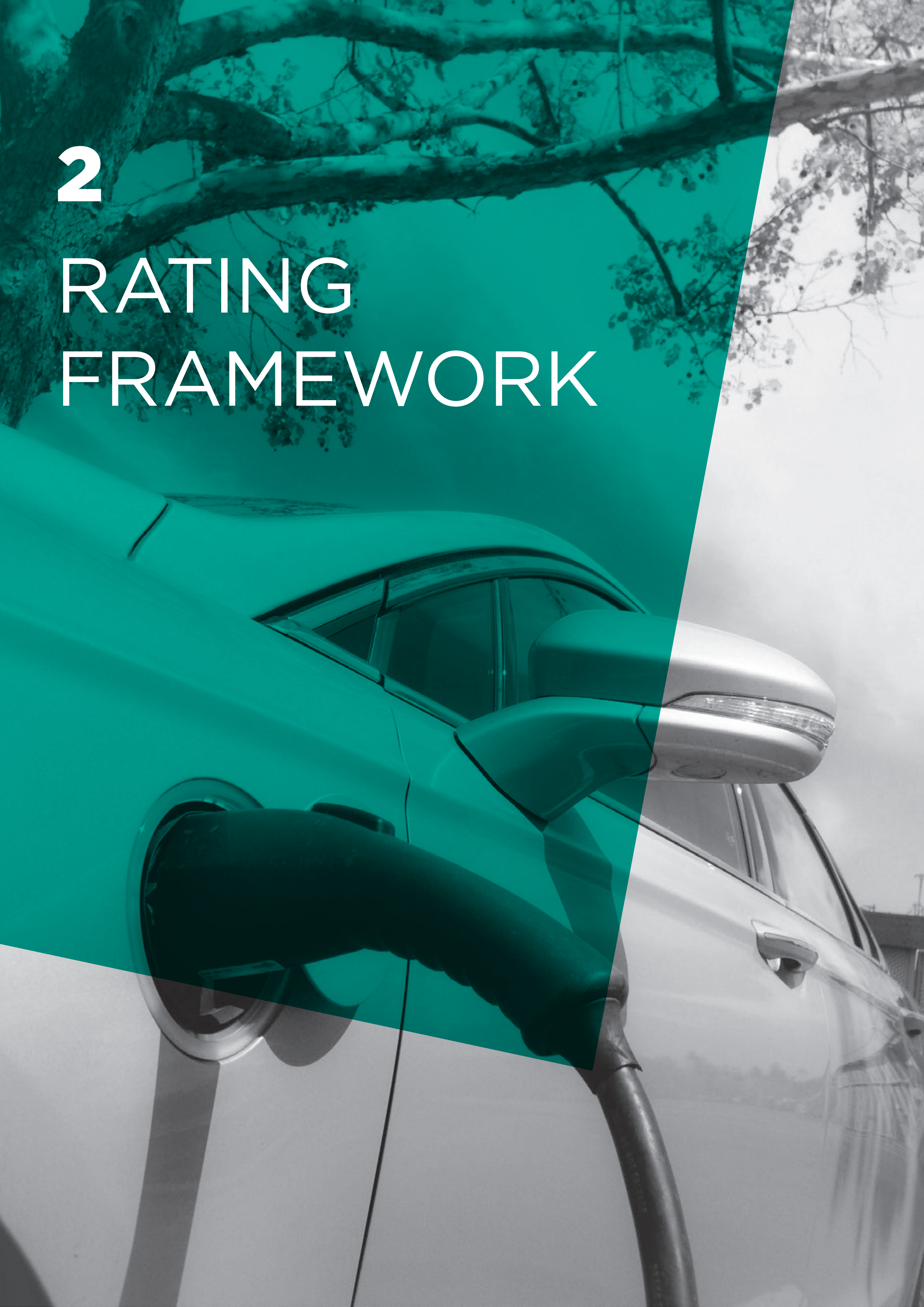
This rating is analytical and driven by hard data. It may therefore not capture some less-quantifiable actions that automakers take toward the ZEV transition. An example is Ford and GM's support of EPA's recent rulemaking on light- and medium-duty vehicles, which demonstrates the commitment of these companies to electrification (EPA, 2024).

As in the previous report, we exclude vehicles that run on biofuels and e-fuels from our analysis, because previous ICCT research has demonstrated that there is no realistic pathway for using alternative fuels to decarbonize new ICEVs sold to the market. Most conventional biofuels used today do not clearly reduce GHG emissions compared with diesel and gasoline. While advanced biofuels made from wastes are more sustainable, they are expensive to produce and the necessary feedstocks are limited. Using e-fuels in internal combustion engines is an extraordinarily inefficient and expensive way to use renewable electricity. Only BEVs and FCEVs using 100% renewable energy are realistic ZEV pathways within the time frame of the Paris Agreement, as discussed in Searle et al. (2021).

While there are many published assessments of auto companies, this rating is unique among publicly available reports in its global scope and focus on a transition to a zero-emission future for the industry, rather than on broad environmental, social, and governance (ESG) criteria. Additionally, this rating is based primarily on our own collected data and analysis, rather than on corporate surveys and other self-reported information. We draw on the ICCT's in-depth knowledge of the industry, major markets, and what is required to align with the Paris Agreement.

2

RATING FRAMEWORK



2 RATING FRAMEWORK

2.1 Scope of the rating

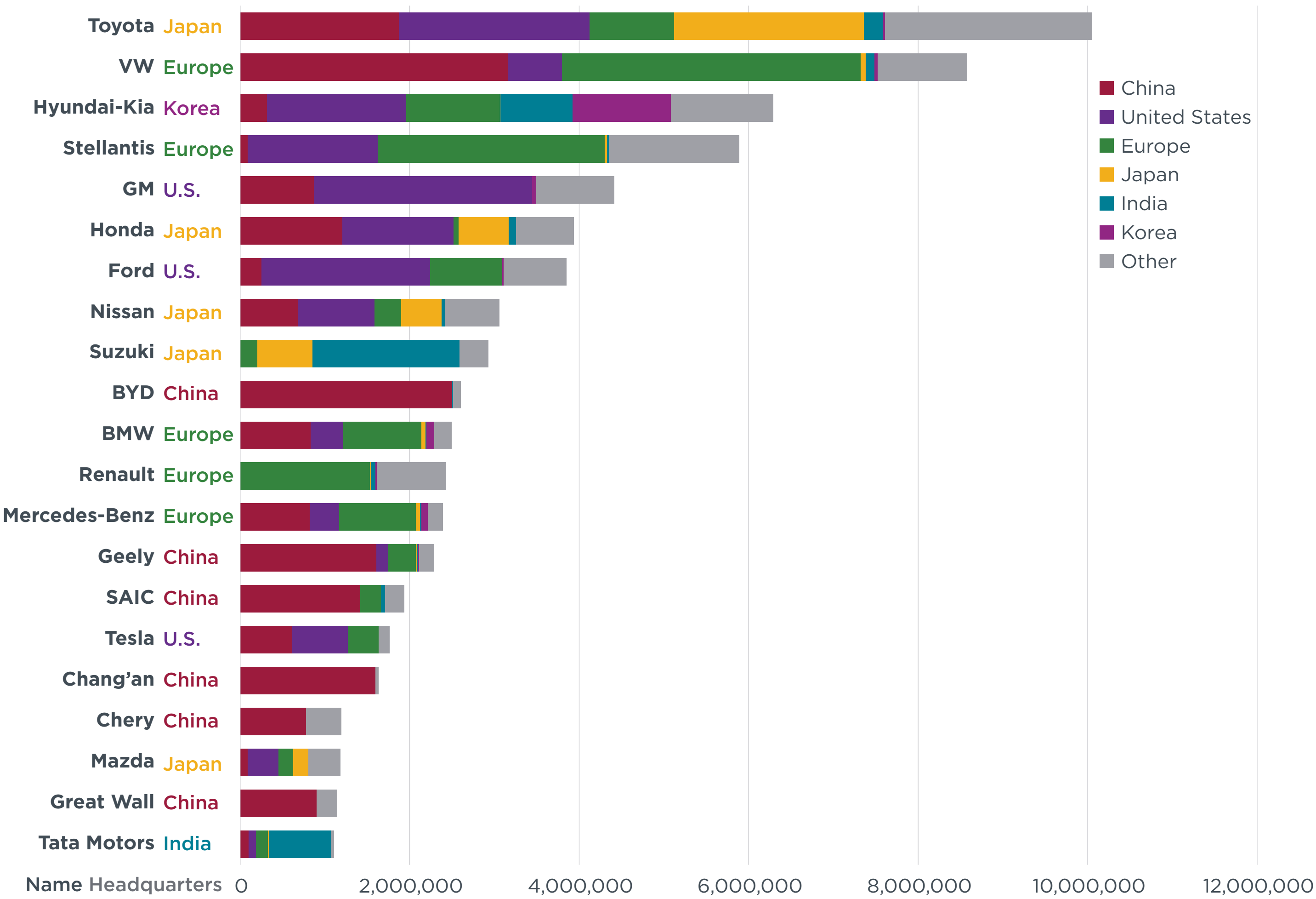
This rating focuses on the production and sale of LDVs, which we define as all cars, pickup trucks, and vans with a gross vehicle weight rating below 3,856 kg in the United States and below 3,500 kg in other key markets. This analysis is based on data developed for auto manufacturers in the six largest LDV markets in 2023: China, the United States, Europe, India, and Japan (the top five markets in terms of LDV sales in 2023) and the Republic of Korea (the eleventh largest in sales and the sixth largest in terms of vehicle production). These six markets have accounted for about 82% of global LDV sales in recent years (MarkLines, 2023).

We selected the top 21 auto manufacturers in the world based on their 2023 global LDV sales. For this rating, “manufacturer” and “automaker” mean the controlling corporate entity. An entity might control multiple automotive brands. For joint ventures in China, manufacturers headquartered outside of China collaborate with a China-headquartered counterpart under a technology-sharing agreement; in these cases, we distinguished between vehicles manufactured under non-domestic or domestic brands and then counted the corresponding sales toward the non-domestic or domestic controlling corporate entity accordingly.

Figure 1 shows the 2023 global LDV sales of the top 21 manufacturers, with color coding representing sales in the six markets investigated in this study and an additional category for sales in the rest of the world. These manufacturers accounted for about 91% of all LDV sales in the six markets. The location beside each automaker’s name indicates where it is headquartered. Six are headquartered in China, five in Japan, five in Europe, three in the United States, one in the Republic of Korea, and one in India. Most of the 21 manufacturers sell in multiple markets.

Figure 1

Light-duty vehicle sales by the top 21 manufacturers in the six major markets, 2023.



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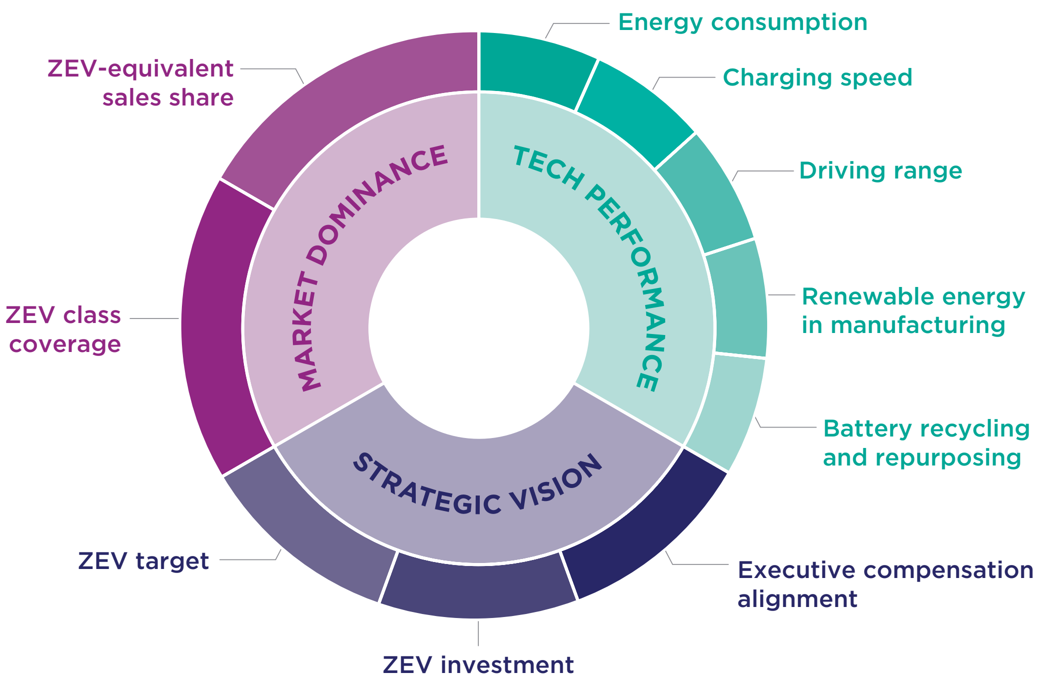
We evaluated manufacturers based on their sales, actions, and strategies in the six markets examined in this study. Vehicle-related analyses were based on new light-duty sales in 2023; analyses of manufacturer actions and strategies were based on information collected through the end of 2023.[1]

2.2 Evaluation structure

We designed the rating around three pillars—market dominance, technology performance, and strategic vision—each made up of particular metrics assessing efforts toward the ZEV transition. There are 10 metrics in total. Figure 2 provides an overview of this analytical structure. The area accorded to each metric in the figure represents its percentage contribution to the final rating.

1 Some information was collected in 2024, to verify the feedback we received from automakers; nonetheless, all information reflects the state of the automakers only through 2023.

Figure 2
Structure of the ICCT's Global Automaker Rating.



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Market dominance reflects the progress each manufacturer has made in its transition to ZEVs. It consists of two metrics:

- *ZEV-equivalent sales share* is the fraction of each manufacturer's LDV sales that are BEVs, FCEVs, and PHEVs. Each PHEV was discounted as a percentage of a ZEV based on the real-world electric drive share of PHEVs, estimated from recent studies.
- *ZEV class coverage* reflects the share of eight LDV classes, ranging from mini/subcompact car to light truck, that are covered by model offerings from each manufacturer. We refined the methodology to differentiate a manufacturer's ZEV offering by market. A class is considered covered if the manufacturer sold at least 1,000 ZEV units in one market.

Technology performance consists of five metrics, three important to consumer experience and two concerned with reducing upstream emissions, which is an important part of decarbonizing the automotive industry. They are:

- *Energy consumption* is the sales-weighted average of certified energy consumption of BEVs sold by each manufacturer, adjusted by vehicle weight and normalized to the same test cycle in units of watt-hours per kilometer (Wh/km).
- *Charging speed* is the average charging speed of BEVs sold by a manufacturer, in kilowatts (kW).
- *Driving range* is the sales-weighted average of certified driving range of ZEVs sold by a manufacturer, normalized to the same test cycle and in kilometers (km).
- *Renewable energy in manufacturing* reflects efforts an automaker has made to move to 100% renewable electricity in vehicle assembly and battery manufacturing.
- *Battery recycling and repurposing* assesses whether manufacturers have planned or implemented battery recycling or reuse projects.

Strategic vision reflects the vision and commitment of each manufacturer in the ZEV transition. It consists of three metrics:

- *ZEV target* is based on each company's stated ZEV sales share targets and dates, and their degree of alignment with the ZEV sales shares needed to keep global warming below 2 °C. As a refinement to the methodology, we evaluated mid-term 2030 targets and long-term 2035 targets if a manufacturer had both, allowing us to track progress throughout the transition.
- *ZEV investment* includes total announced investments in ZEV and battery production sites, charging infrastructure, and ZEV research and development relative to an automaker's size. Additionally, this metric newly includes investment in battery raw materials, which considers procurement agreements and direct investment in the mining supply chain.
- *Executive compensation alignment* reflects the extent to which an automaker's top executive's pay is tied to EV development. A manufacturer is awarded credits for linking its executive compensation to parameters associated with EVs and CO_2 emissions. As a refinement of the methodology, we no longer give credits to parameters associated with broad ESG performance.

We award manufacturers points according to their performance on each metric. The highest possible score in each metric is 100; the lowest is zero. Although, by definition, some metrics have an absolute best and worst performance—as in the case of ZEV sales shares of 100% (best) or 0% (worst)—metrics like energy consumption, charging speed, and driving range have no absolute best or worst. To create an evaluation mechanism that equally applies to all metrics, we use the historical best and worst performers on each metric as benchmarks for scores of 100 and 0, respectively, based on data from reporting years 2022 and 2023. When there is a methodological change in this report, we recalculate 2022 performance based on the revised methodology to determine the historical best and worst performers. Using historical performance as a benchmark enables us to compare automakers within the same reporting year and track their improvement over time.

We applied Equation (1), below, to calculate the final score for each manufacturer for each metric:

$$\textit{Metric score (0 to 100 scale)} = \frac{Points - Points_{min}}{Points_{max} - Points_{min}} \times 100 \qquad (1)$$

Where

Points is the number of points for the metric awarded to a given manufacturer;

$Points_{min}$ is the lowest number of points awarded for the metric (considering all manufacturers) across reporting years 2022 and 2023; and

$Points_{max}$ is the highest number of points awarded for the metric (considering all manufacturers) across reporting years 2022 and 2023.

Each pillar score is calculated as the average of the metric scores within that pillar. If any metric is not applicable for a particular manufacturer, we average the scores of the other metrics to get the pillar score.[2] Because there are different numbers of metrics within each pillar, the comparative weighting of individual metrics is the same within each pillar, but different from the individual metrics in other pillars. The final rating is calculated as the average of the three pillar scores, which are assigned the same weight

2 Suzuki received an N/A for the energy consumption, charging speed, and driving range metrics because it did not sell any ZEVs in 2022. It was the only automaker to receive an N/A for any metric.

because they are equally important. While all averages are done without rounding, the results reported are rounded to the nearest integer.

2.3 Data sources and process

Five of the metrics assessed in this rating are at the vehicle level and the other five are at the manufacturer level. Vehicle-level metrics are ZEV-equivalent sales share, ZEV class coverage, BEV energy consumption, charging speed, and driving range. Manufacturer-level metrics are ZEV target, ZEV investment, executive compensation alignment, renewable energy in manufacturing, and battery recycling and repurposing. Data sources are described below.

For vehicle-level data, we developed a database that includes all new LDVs sold in 2023 by the manufacturers in the six vehicle markets. We obtained vehicle data from multiple sales databases to maximize data coverage and accuracy. Vehicle sales and vehicle powertrain type data for new vehicles sold in 2023 were derived from four sources. U.S., Korea, and Japan data were from MarkLines (MarkLines, 2023); Europe data, including vehicle sales in the European Union, European Free Trade Association (EFTA) member states, and the United Kingdom, were from Dataforce (Dataforce, 2023); India data were from Segment Y (Segment Y, 2023); and China data were from WAYS (WAYS, 2023). For European and U.S. models, data on specifications (length, gross weight and curb weight, gross battery capacity, energy consumption, driving range, charging time, and PHEV charge-depleting range) were collected from specification brochures on manufacturers' official websites and from major EV information hubs, including ev-database.org, evspecifications.com, and EV-volumes (EV-volumes, 2023). The corresponding data for Chinese models were collected from yiche.com and autohome.com. To develop a comprehensive set of globally consistent data, variations in the level of detail among the various datasets required substantial processing. Appendix A describes the methodology used in the creation of this database.

For manufacturer-level data, information about the use of renewable energy in manufacturing, battery recycling and repurposing, ZEV targets, ZEV investments, procurement agreements and direct investments in battery raw materials, and charging infrastructure were primarily sourced from the manufacturers' latest annual sustainability reports.[3] The reports could come from either the parent company or the subsidiary company, if the latter publish separate sustainability reports. This was supplemented with publicly available data from press releases, media articles, and public announcements collected through the end of 2023, to capture any developments between the publication of the sustainability report and the end of the year. Some automakers provided feedback to our input information by referring to their sustainability reports published in 2024. We incorporated that information into this rating if it reflected the automakers' efforts in 2023.

Data used to assess manufacturers' investments in ZEVs were obtained from Atlas Public Policy's EV Hub and verified with publicly available information from manufacturers' reports and official announcements. Information regarding the mechanism behind, and elements used in, determining executive compensation was extracted from proxy statements and other public filings of each manufacturer and cross-validated by Valens Research.[4] Detailed information on data sources is presented in the methodology section for each individual metric. Table A1, in Appendix A,

3 In some cases, annual sustainability reports were identified by the companies as environmental, climate, or ESG reports. For simplicity, we refer to all of these as "annual sustainability reports" throughout this study.

4 Valens Research is an investment research firm specializing in accounting analytics and corporate valuation and performance.

includes the complete list of annual sustainability reports and supplementary sources reviewed for this analysis.

Most of the top 21 manufacturers operate in multiple major markets, and corporate practices and ambitions can differ across regions. For example, some manufacturers adopted 100% renewable electricity in manufacturing in Europe, but not in other markets. Similarly, the same manufacturer might announce different ZEV targets and ICEV phase-out dates for Europe, the United States, and other regions. To account for such differences, we collected manufacturers' global and regional strategies and implementation actions from the sources described above. Whenever regional practices diverged, we calculated global average performance metrics weighted by vehicle sales in the corresponding regional markets.

To ensure the accuracy and timeliness of the manufacturer-specific information used for this rating, we asked all 21 automakers to review the input data and information used for evaluating manufacturer-specific actions and commitments. We received feedback from 13 automakers: BMW, Ford, Geely, GM, Great Wall, Mercedes-Benz, Nissan, Renault, SAIC, Stellantis, Tata Motors, Tesla, and VW. When automakers disagreed with our information, they generally provided revised or updated data, which were used for the analysis if we were able to verify it.

3

MARKET DOMINANCE

3 MARKET DOMINANCE

3.1 ZEV-equivalent sales share

The ZEV-equivalent (ZEVe) sales share, which represents the share of an automaker's total LDV sales that are ZEVs, is the most direct measure of progress in the ZEV transition. The ZEVe sales share is the sum of a manufacturer's ZEV share and the discounted PHEV share. ZEVs are BEVs with no additional power source or FCEVs. PHEVs are hybrid vehicles equipped with an internal combustion engine, an electric motor, and a battery that can be recharged with an external electric power source. They are considered partial ZEVs, because they can be driven for a period with zero tailpipe CO_2 emissions. The discount factors for PHEVs in this evaluation are based on real-world statistics.

METHODOLOGY

Vehicle sales data are from the compiled vehicle sales database explained in Section 2.3, which reflects all new LDVs sold in the six major markets in 2023.

While each BEV or FCEV sold counts as one ZEV, we discounted a portion of PHEV sales using a factor based on real-world electric drive share (i.e., the portion of kilometers driven on electricity). The discount factors reflected the non-electric driving share. Recent research estimated that the real-world electric drive share of PHEVs in the United States is 25%–56% lower than indicated in EPA's labeling program (Isenstadt et al., 2022). Studies also found lower real-world electric drive share in Europe and China (Plötz et al., 2020; Plötz et al., 2022). Using the real-world electric drive share to discount PHEV sales share reflects the more limited climate benefits PHEVs deliver compared to BEVs and FCEVs.

The PHEV discount factor depended on the electric driving range of the model. Real-world data show that, in general, the longer the all-electric range of a PHEV, the larger the share of all-electric, zero-tailpipe-emissions driving. For each PHEV model, the discount factor we applied to determine the ZEVe share was calculated by an equation that related a model's charge-depleting range to its real-world electric drive share. Details of this calculation are presented in Appendix C.1; the sources of PHEV charge-depleting range data are described in Section 2.3. The sales-weighted average of the discount factor for all PHEVs sold by the top 21 automakers in the six major markets was 58%, which is lower than the average discount factor in 2022—a result of an increase in the average electric drive range of PHEVs.

ZEVe sales share ranges from 0%–100%. We identified the historical best and worst performers based on data from reporting years 2022 and 2023. We assigned a score of 100 to the best performer and a score of zero to the worst performer on this metric. Other manufacturers were scored based on their points relative to the best and worst performers and received a score between zero and 100 (see Equation [1]).

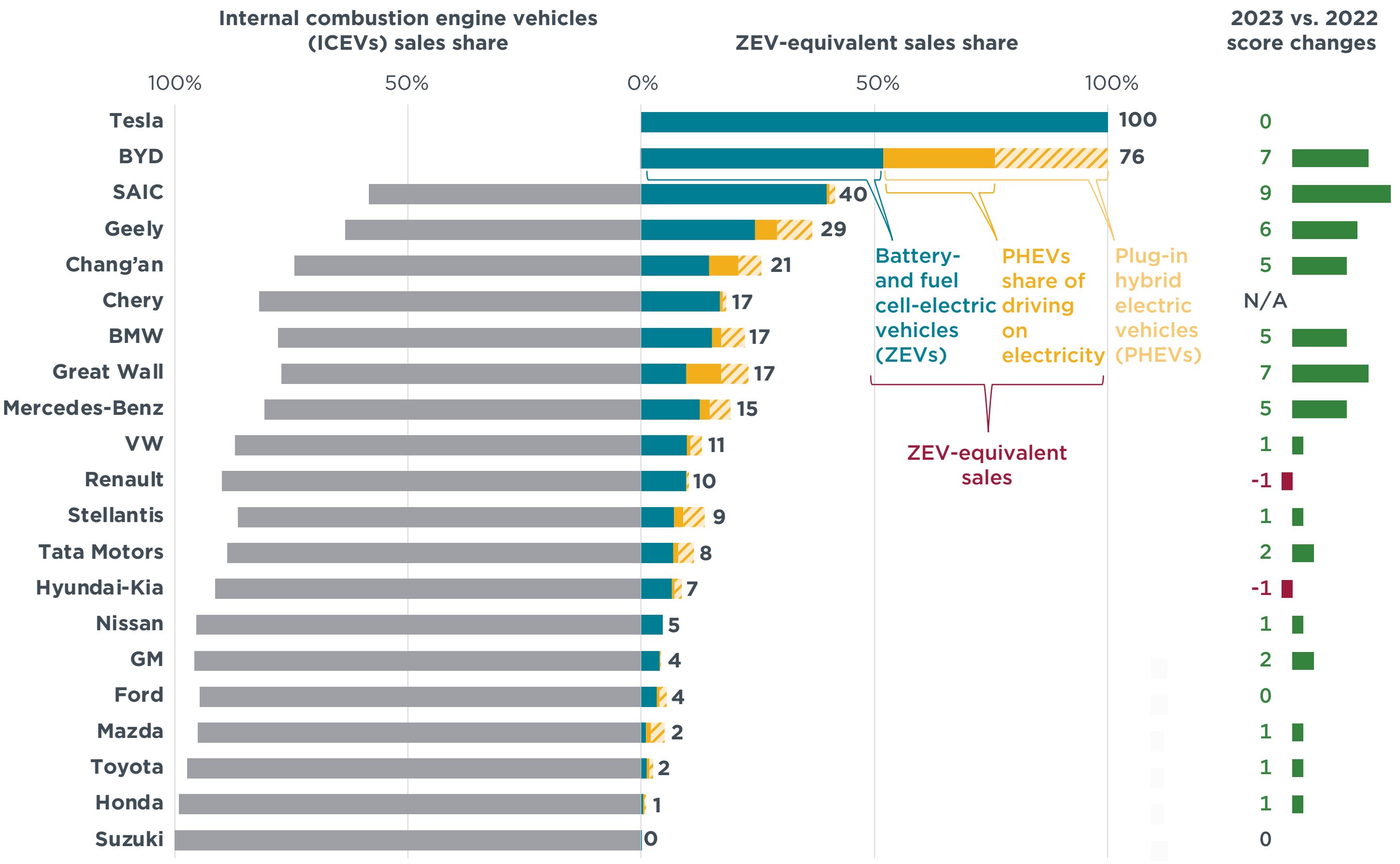
RESULTS

The overall ZEVe sales share of the top automakers in the six markets increased from 11% in 2022 to 15% in 2023. There were large variations in manufacturer sales shares. Tesla was still the only 100% ZEV manufacturer. The China-based automakers achieved ZEVe sales shares ranging from 17% to 76%, higher than most other automakers.

Figure 3 summarizes the global ZEVe sales shares of LDVs by manufacturer in 2023 and the score changes compared with 2022. The left section shows the sales share of ICEVs, represented by gray bars. The central section shows the ZEVe sales share, where blue bars reflect the sales share of BEVs and FCEVs and yellow bars represent the actual PHEV sales share. The solid yellow bars reflect the ZEVe portion of the PHEV sales share, which is the electric drive proportion calculated using real world data; the shaded yellow bars, on the other hand, represent the non-electric drive proportion and thus do not count toward the total ZEVe share. The numeric scores for each automaker are presented to the right of each bar. The rightmost section of the figure highlights the year-over-year score changes between 2022 and 2023 for each manufacturer, with green bars indicating an increase and red bars denoting a decrease. Details on ZEV and PHEV sales shares by manufacturer across the six major markets and score comparisons between 2022 and 2023 are presented in Table B1 in Appendix B.

Figure 3

ZEV and PHEV sales shares by manufacturer and ZEVe sales share metric scores, 2023.



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BEVs made up the majority of ZEVe sales for most manufacturers, though PHEV sales comprised a sizable share of sales for some automakers, including China-based manufacturers BYD, Geely, Chang'an, and Great Wall. FCEV sales were minimal, making up 0.1% of all ZEV sales by the 21 manufacturers; 95% of those sales were by Hyundai-Kia and Toyota, while the remaining sales were split between Honda, Stellantis, and BMW.

Tesla maintained a 100% ZEVe sales share, as it only produced BEVs. BYD, having transitioned to 100% EV (BEV and PHEV) production in March 2022, followed with a 76% ZEV-equivalent sales share, marking a 7 percentage point improvement from 2022.

Although this analysis focuses on the conventional automakers' progress in the ZEV transition and does not consider the absolute increase in EV sales for EV-only manufacturers, it is worth noting that both BYD and Tesla made substantial progress in growing total EV sales. BYD almost doubled its EV (BEV and PHEV) sales from 2022 to 2023 and Tesla increased its ZEV sales by 40%.

China-based manufacturers SAIC, Geely, Chang'an, and Great Wall were among the top movers, with 5–9 percentage point increases in ZEVe share. SAIC achieved a 40% share, placing third behind Tesla and BYD. Geely, Chang'an, and Great Wall reached 29%, 21%, and 17% shares, respectively. Among manufacturers headquartered in Europe, BMW and Mercedes-Benz saw the greatest improvements, of 5 percentage points. Renault and Hyundai-Kia were the only two manufacturers that saw declines in ZEVe share, of 1 percentage point each.

U.S.-based and Japan-based manufacturers saw minor gains in their ZEVe shares, with none surpassing more than a 2 percentage point increase from 2022. Suzuki continued to receive a score of zero with a combination of zero ZEV sales and a PHEV sales share of 0.03%.

3.2 Class coverage

Automakers often sell a variety of models across many vehicle classes or segments to attract a broad range of customers, whose requirements when selecting a vehicle for purchase vary based on many factors. The class coverage metric evaluates the diversity of BEV and FCEV models offered by manufacturers and how well they cater to different market segments. Manufacturers with broader class coverage have invested in vehicle technology and production platforms to serve different submarkets. We expect this wider range of coverage to give manufacturers an advantage as the ZEV market grows, as it would allow them to access a larger customer base. Selling a variety of ZEV models also supports the overall transition by increasing consumer choice. As this metric reflects manufacturers' efforts toward a zero-tailpipe-emissions future, PHEV models are excluded.

METHODOLOGY

There are no universal definitions of vehicle classes. Consequently, combining data from major vehicle markets results in inconsistent vehicle classifications. To address this, we used a simplified classification system based on vehicle length for passenger cars (PCs) and curb weight for light commercial vehicles (LCVs) and apply it to the ZEV data from all six markets. We classified passenger cars into five classes (mini/subcompact car, compact car, midsize car, large car, and sport utility vehicle/multi-purpose vehicle, or SUV/MPV) and LCVs into three classes (small, medium, and large), for a total of eight defined classes. The length thresholds for PC classification are based on EV-Volumes' global segment classification (EV-Volumes, 2023), and curb weight thresholds for LCV classification are based on the EU N1 subclasses standard (Regulation 715/2007, 2007). We combined the mini class with the subcompact class to reflect model availability in the smaller PC segment. Weight thresholds for LCVs are detailed in Appendix C.

Since batteries are heavy, BEVs typically weigh more than their ICEV counterparts. Because EU curb weight classifications were initially designed for ICEVs, directly mapping BEVs into their corresponding weight classes might lead to inaccurate categorization. For this reason, we adjusted the curb weight of BEVs to be comparable with their ICEV equivalents for LCV classification. To determine the appropriate adjustment factor, we calculated the ratio of curb weight of 10 popular ICEV models and their ZEV counterparts of nearly identical size. The average curb weight ratio was found to be 0.83. This average ratio was used as a discount factor to estimate the ICEV-equivalent curb weight of each BEV model. This method proved effective in reasonably estimating ICEV-equivalent curb weights for ZEV models across a wide range of curb weights (see Appendix C.2). Then we compared the adjusted curb weight against thresholds from the EU N1 subclasses standard to determine the vehicle class of each LCV BEV model.

We made two changes to our evaluation methodology in this report. First, while our 2022 report gave automakers full credit for offering vehicles of a certain class in at least one of the six markets, we now award only partial credit for not offering the vehicle class in all markets. To do so, we evaluated a manufacturer's class coverage in each of the six markets analyzed, then aggregated to the final class coverage weighted by the LDV sales in each major market. Second, while we previously did not set a minimum number of unit sales, we now consider a defined class to be covered only if the manufacturer sold at least 1,000 ZEVs of that class in that market. In our analysis, we found that most models with sales under 1,000 in 2022 or 2023 in one market were discontinued between 2019 and 2023. These results suggest that models with sales under 1,000 are unlikely to contribute to an automaker's present or future global market dominance or to the overall ZEV transition.

The class coverage rate is the ratio of the total number of classes covered by the manufacturer to the total number of classes considered (eight). For instance, if the ZEV models sold by a manufacturer cover four out of the eight classes in one market, we assigned a score of 4/8 (50%) for this market. We averaged the score for each market, weighting by total LDV sales in each market, to derive the aggregated score for this metric.

Lastly, we converted the coverage rate to the 100-point system using the historical highest and lowest coverage rate as the benchmark. Our revised methodology for 2023 is more restrictive for this metric than the methodology we used in our 2022 report, which would reduce the scores for many automakers, even if their actual ZEV offerings did not change. To mitigate this problem, we reevaluated the class coverage rate for the 2022 fleet using the updated methodology to identify the historical best and worst performers in 2022 and 2023, which we assigned scores of 100 and zero, respectively. Other manufacturers were scored based on their relative points on this metric compared with the best and worst performers and received a score between zero and 100 (see Equation [1]).

RESULTS

Overall, the total number of ZEV models offered increased from 2022 to 2023 in each of the six markets, by between 10% and 42%. The trend was uneven across automakers, however. Almost all manufacturers offered ZEV models in the SUV/MPV class; the exception was Suzuki, which had no ZEV models in any class and offered only plug-in hybrid SUVs. Several manufacturers sold a wide variety of BEV models that covered more than half of all classes in the studied markets. Table 1 summarizes class coverage across all six major markets and the final scores for this metric. To the right, we show our original 2022 rating, as well as an adjusted 2022 rating using the updated methodology for consistent comparison across years.

Table 1

ZEV (BEV and FCEV) model class coverage for each manufacturer.

OEM	Class coverage by region						2023 sales-weighted average	2023 score	2022 adjusted score[a]	2022 original score
	China	U.S.	Europe	Japan	India	Korea				
SAIC	88%	0%	50%	0%	25%	0%	80%	100	96	100
Chang'an	75%	0%	0%	0%	0%	0%	75%	93	100	88
Geely	75%	25%	25%	13%	0%	25%	63%	78	83	88
Chery	63%	0%	0%	0%	0%	0%	62%	78	N/A	N/A
BYD	63%	0%	25%	13%	13%	0%	62%	77	83	88
Renault	25%	0%	63%	0%	0%	0%	59%	74	60	75
Stellantis	25%	0%	88%	0%	13%	0%	54%	68	60	88
VW	38%	25%	63%	13%	0%	25%	47%	59	65	88
BMW	38%	50%	50%	13%	0%	38%	44%	55	43	50
Mercedes-Benz	25%	25%	63%	13%	0%	25%	40%	50	47	63
Great Wall	38%	0%	13%	0%	0%	0%	37%	46	67	75
Tesla	38%	38%	38%	25%	0%	13%	37%	46	38	38
Hyundai-Kia	0%	25%	25%	0%	13%	38%	24%	30	32	63
Ford	13%	25%	25%	0%	0%	0%	24%	30	27	25
Nissan	13%	25%	38%	25%	0%	0%	23%	28	22	63
Toyota	25%	25%	38%	13%	0%	0%	22%	28	26	63
Tata Motors	0%	0%	13%	0%	25%	0%	19%	23	27	25
GM	25%	13%	0%	0%	0%	13%	16%	19	21	38
Honda	13%	0%	13%	0%	0%	0%	5%	6	8	38
Mazda	0%	0%	13%	0%	0%	0%	3%	3	3	13
Suzuki	0%	0%	0%	0%	0%	0%	0%	0	0	0

[a] Adjusted 2022 scores reflect revised methodology for consistent comparison across years.

SAIC led with a sales-weighted class coverage of 80%, receiving a score of 100. Chang'an followed with a score of 93. China- and Europe-based manufacturers continued to perform above average while Japan- and U.S.-based manufacturers performed below average. Suzuki again received a score of zero for not having any ZEV models in 2023. Several automakers dropped in score from 2022 because they discontinued products or had low sales in certain classes, while others did not provide the same variety of ZEV models across all markets where they have business.

Chang'an, Geely, VW, Hyundai-Kia, Nissan, Great Wall, and Honda saw decreases in class coverage as they discontinued certain models that had seen declining sales until they were completely phased out. Specifically:

- Geely's ZD D2 BEV (mini/subcompact PC) was discontinued in 2019.
- Chang'an Yidong ET BEV (compact PC) was discontinued in 2019.
- VW's eTransporter (medium LCV), one of the brand's first fully electric vans, was discontinued in early 2022 (Errity, 2022). VW's Langyi BEV (midsize PC) was discontinued in 2021.

- Hyundai-Kia's Ioniq Electric (compact PC), originally introduced in 2016, was discontinued in 2022 (Kane, 2022). Kia's K3, which was available in China, was discontinued in 2021.
- Nissan discontinued its E-NV200 BEV (medium LCV) in 2021 (Smith, 2021). Nissan's Xuanyi BEV, available in China, was discontinued in 2020.
- Great Wall's Black Cat (mini/subcompact PC) was discontinued in 2022 (Ifeng, 2022).
- Honda discontinued its Clarity FCEV (midsize PC) in 2021 and its Honda-e BEV (mini/subcompact PC) in January 2024 (Misoyannis, 2023).

Some models that were discontinued were included in our original 2022 scoring but were excluded from the adjusted 2022 scores after we applied the 1,000 unit threshold. BYD and Great Wall were also affected by the 1,000 sales threshold as both had models with sales below 1,000 in the large and medium LCV classes.

Several other manufacturers, including Nissan, Toyota, Honda, Hyundai-Kia, Stellantis, and VW, experienced substantial decreases in their scores when the 1,000 threshold was applied because they only sell ZEVs in certain markets. For instance, Toyota's ZEV models cover five out of eight classes across all six markets. However, it sold no more than three classes in each market; furthermore, in its largest market, Japan, where it sold 30% of LDVs, its sales only surpassed 1,000 in the SUV/MPV class. To improve, these manufacturers should enhance the variety of ZEV classes they offer in the markets where they sell LDVs.

As in our previous evaluation, there were factors that this metric did not capture equally across all automakers. For instance, Tesla's offerings were in a limited range of classes, but it sold exclusively BEVs. Other manufacturers had multiple ZEV models at a variety of price points, but within only a few classes. While these manufacturers might thus be better positioned to sell within those classes today, their customer base is more limited. Additionally, the popularity of PCs and LCVs varies across the six major markets, and some automakers might offer models in certain classes because of the popularity of those classes in a certain market. Still, this analysis is global in scope; most of the automakers assessed operate globally. Therefore, the more classes an automaker covers, the more they contribute to the global ZEV transition across all vehicle classes.

4

TECHNOLOGY PERFORMANCE

4 TECHNOLOGY PERFORMANCE

4.1 Energy consumption

The energy consumption metric evaluates the sales-weighted average certified energy consumption of BEVs sold by each manufacturer. Energy consumption measures the amount of energy consumed per distance traveled. For vehicles with the same battery size, the more efficient vehicle can drive longer distances per charge. BEVs that consume less energy consume less electricity and help limit the upstream emissions from vehicle use. Vehicles that consume less energy also reduce energy costs for consumers.

METHODOLOGY

We computed the energy consumption of each BEV model in our database by dividing the net (usable) battery capacity by the certified driving range, expressed in Wh/km. The resulting energy consumption values were usually lower than the rated energy consumption reported to regulatory agencies, which take account of charging losses. However, because rated energy consumption data were not equally available for most markets, we used the calculated energy consumption for comparison. For models for which no data on net battery capacity are available, a multiplier of 0.95 was applied to the gross battery capacity, which was estimated from regression analysis using 228 models with both net and gross battery capacity information available. The regression analysis used an ordinary least squares (OLS) model to regress the net battery capacity on gross battery capacity.

FCEVs were excluded from the calculation of fleet average energy consumption because they operate differently than BEVs. Compared with the direct use of electricity from batteries in BEVs, which is more than 70% efficient, the process of generating electricity from hydrogen through a fuel cell is only approximately 50% efficient. This causes FCEVs to consume almost twice as much electric energy as comparable BEVs.

Energy consumption data were calculated from the certified driving range values that were measured using different test cycles, such as the Worldwide harmonized Light vehicles Test Procedure (WLTP), New European Driving Cycle test cycle (NEDC), China Light-Duty Vehicle Test Cycle (CLTC), and the U.S. label value used by EPA. Energy consumption values from the different test cycles were standardized to WLTP-equivalent values by using conversion factors. We applied a multiplier of 1.15 to convert the NEDC or CLTC energy consumption to its equivalent value under the WLTP test cycle (Yoney, 2022). Similarly, a discount factor of 1.2 was used to convert the U.S. label values to their equivalent values under the WLTP (Yoney, 2022). These conversions allow for a consistent comparison of energy consumption across models.

We adjusted the energy consumption of each BEV model to account for the weight differences of vehicles, as physical differences inherently affect energy consumption. The impact is shown in our analysis: Regressing energy consumption on curb weight using all BEV models in our database showed a high statistical correlation between the two variables (see Appendix C.3 for details). BEVs were sold in different vehicle classes across manufacturers. For example, all BEVs sold by Ford were SUVs or LCVs with an average curb weight of 2,540 kg. The data also show that more than 81% of BEVs sold by SAIC were subcompact or compact cars that had an average curb weight of 1,178 kg. Thus, the adjustment allows manufacturers to be compared independent of the size of the vehicles they sell.

For the weight adjustment, we benchmarked the energy consumption of each model to the same baseline weight of 1,733 kg, which is the sales-weighted average curb weight of all new ZEVs sold by the top 21 automakers in 2023 in the six markets. The regression result based on the 2023 fleet showed that, on average, each kilogram increase in curb weight is correlated with a 0.052 Wh/km increase in energy consumption. For a model that is 100 kg heavier than the baseline of 1,733 kg, we adjusted the energy consumption downward by 100*0.052 = 5.2 Wh/km to normalize the energy consumption. On the other hand, for a model that is lighter than the baseline, the energy consumption was adjusted upward. These parameters showed a slight variation from the adjustment factors we used for the 2022 report, which were derived using the 2022 fleet with a baseline weight of 1,773 kg and a correlation of 0.056 Wh/km. We updated our adjustment factors to represent the current fleet trends more accurately. To reflect the impact of the updated adjustment factors, we recalculated the adjusted energy consumption for the 2022 fleet using both sets of parameters (See Appendix C.3)

With the adjusted energy consumption of each model, we calculated the sales-weighted average energy consumption for each manufacturer. The adjusted energy consumption values were then converted to a 100-point score using the historical highest and lowest fleet-average energy consumption as the benchmark. After comparing the 2022 and 2023 values, we assigned a score of 100 to the historical best performer with the lowest sales-weighted average energy consumption and a score of zero to the historical worst performer with the highest sales-weighted average energy consumption. Other manufacturers were scored based on their relative metric points compared with the historical best and worst performers and received a score between zero and 100 (see Equation [1]).

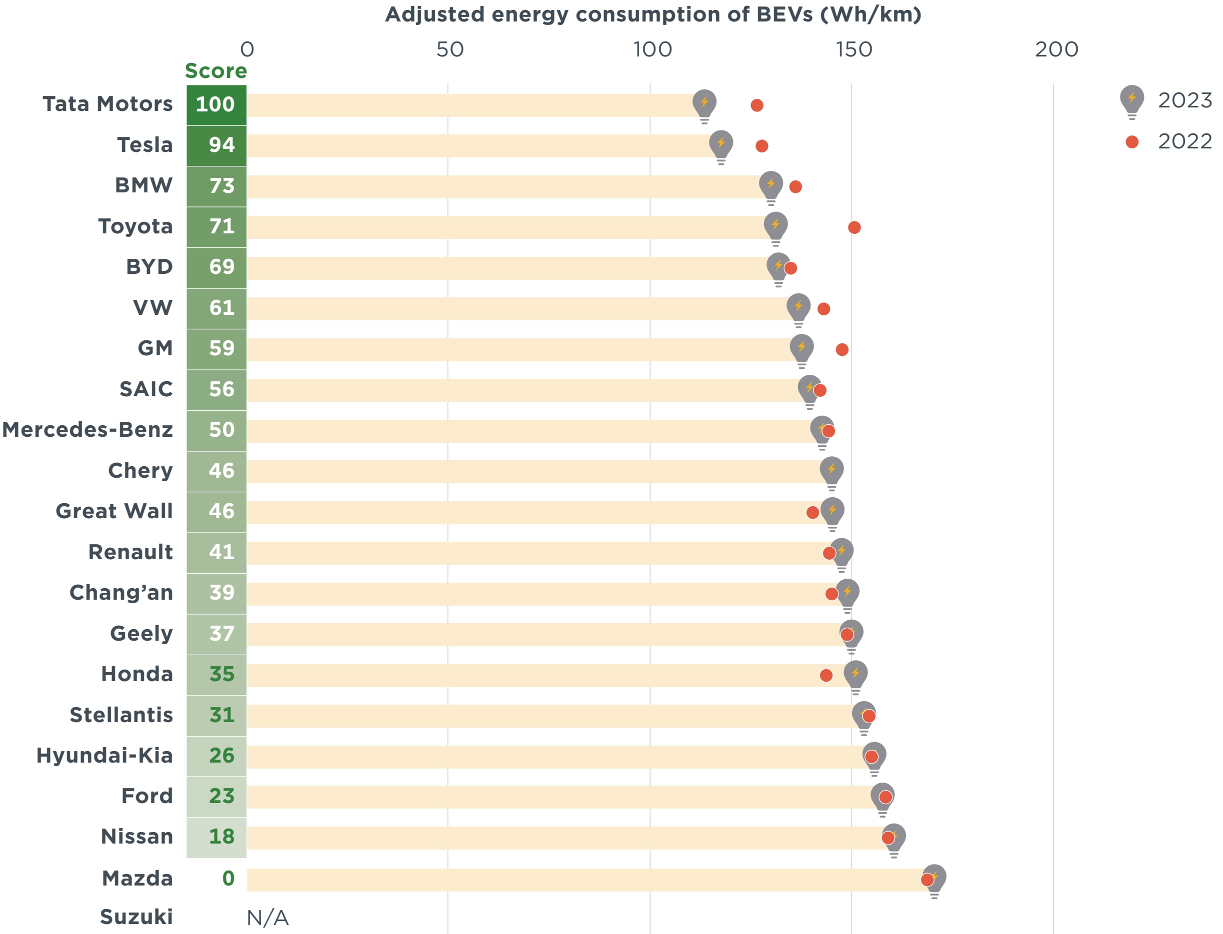
We acknowledge the difference between real-world and reported values and the potentially different degrees of divergence across brands (Komnos et al., 2022; Jin et al., 2023; Al-Wreikat et al., 2021; Kothari, 2023). However, there are no ideal real-world data sources that cover the wide range of models and brands in this analysis. In the absence of a high-quality real-world database, we used certified values from the vehicle type-approval process. This also reflects the information given to consumers in the official specifications of a manufacturer's offerings. If sufficient real-world data on energy consumption becomes available in future years, we will aim to incorporate them into our assessment for this metric.

RESULTS

Like the variance in fleet-average fuel consumption of ICEVs across manufacturers, we see noticeable differences in BEV energy consumption. On average, the energy consumption of BEVs across top automakers declined from 140 Wh/km in 2022 to 135 Wh/km in 2023. The energy consumption of the lowest-scoring automaker, Mazda, is about 49% higher than that of the highest-scoring automaker, Tata Motors. Figure 4 illustrates the average energy consumption of BEVs after the adjustment by vehicle curb weight and the score for this metric, by manufacturer. Shorter bars illustrate lower average energy consumption, which translates into a higher metric score. Red dots show the corresponding 2022 value of this metric for each manufacturer. The adjusted energy consumption for 2022 was recalculated using 2023 regression parameters to ensure a consistent and fair comparison. Data on the average energy consumption of BEVs before and after the adjustment by weight are presented in Appendix B, Table B2. The table shows original and adjusted energy consumption for both the 2022 and 2023 fleet and compares scores between these two reporting years.

Figure 4

Average energy consumption of BEVs and metric scores by manufacturer.



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Tata Motors and Tesla continued to lead on this metric, with adjusted energy consumption of 114 Wh/km and 117 Wh/km, respectively. Compared with 2022, 11 automakers demonstrated improvements in fleet-average energy consumption. Some improvements can be attributed to a shift in fleet composition. For instance, the sales share of Toyota's relatively more efficient bZ4X (adjusted energy consumption of 113 Wh/km) increased from 19% in 2022 to 36% in 2023, while sales of Toyota's less efficient Proace Van BEV (adjusted energy consumption of 235 Wh/km) declined from 23% to 7%, contributing to a reduction in the average energy consumption of its fleet. Improved efficiency has enabled some automakers to release updated models with the same battery capacity but a longer electric range. For instance, the 2023 Tesla Model 3 (60 kWh) has a WLTP range of 554 km, up from the 495 km range of the 2022 model with the same battery capacity.

Honda was the only automaker to experience an increase of more than 5 Wh/km in their fleet's average energy consumption, both before and after curb weight adjustments. This was primarily due to the introduction of a new model, the Honda e:Ny1, which has a higher adjusted energy consumption than its previous fleet average.

4.2 Charging speed

Concerns about the length of charging time, especially when charging during long-distance travel, can significantly impact consumer BEV purchase decisions (Li et al., 2020). Although some direct current (DC) fast chargers can deliver power up to 350 kW, there are large differences in the average rate of charge that can be accepted by the vehicles themselves. For example, the Hyundai IONIQ 5 supports 350 kW DC charging and has an average charging speed of 169.4 kW; it takes 18 minutes to charge its 72.6 kWh batteries from 10% to 80%. Meanwhile, the Citroën Ami from Stellantis has a comparatively weak 3.6 kW onboard charger and requires 4 hours to fully charge its 5.5 kWh variant. Given the importance of charging time in BEV adoption, this metric can provide insight into the attractiveness of BEV models' charging options.

METHODOLOGY

For this metric we calculated the sales-weighted average charging speed of BEV models sold by each manufacturer. Like energy consumption, we excluded FCEVs because of the difference in the technology and refueling processes. To calculate the charging speed for each BEV model, information on net battery capacity and charging time of all compatible chargers was collected and compiled into a ZEV specification database (see Section 2.3). As with energy consumption, for models for which no data on net battery capacity are available, a multiplier of 0.95 was applied to the gross battery capacity.

Data on the charging speed of BEV models are typically provided by automakers for normal chargers and fast chargers. Normal chargers are Level 2 home, workplace, and public chargers with typical power ratings between 3 kW and 22 kW from alternating current (AC; Rajon Bernard et al., 2021). Fast chargers are typically DC with power ratings between 50 kW and 350 kW. In this analysis, charger type definitions follow the European Court of Auditors (2021); for details, see Appendix C.4. All BEV models accept normal chargers, but only some BEV models are capable of DC fast charging. The maximum charging speed possible with DC fast chargers varies by vehicle model.

For BEV normal charging, each model's average charging speed is calculated by dividing its net battery capacity by the amount of time needed to charge from 0% to 100%. For BEV fast charging, the average charging speed is based on 70% of the net battery capacity and the time needed to charge the battery from 10% to 80%, which is the value manufacturers typically provide for fast charging. This range is also more representative of the real-world use of fast chargers, as most drivers fast charge between 20% and 80% state of charge, and because charging speed typically slows down significantly above 80% (Whaling, 2022). As the battery approaches full capacity using a fast charger, the battery management system slows the charging rate to avoid overcharging and to prolong the battery's life. Therefore, we define the average charging speed for fast charging as the net battery capacity in kWh multiplied by the charged percentages of 70% divided by the time, in hours.

In 2023, there was an increase in battery swap capable BEV models among China-based manufacturers, such as the Maple 60s and 80v from Geely and the Rising Auto R7 and F7 from SAIC. Despite this growth, battery swap capable BEVs still represented a small sales share (less than 1%) among all BEVs and were primarily designed for taxi services (Ofweek, 2023). All EVs capable of battery swapping also offer non-swapping charging options. For our evaluations, we only assessed the non-swapping charging speed of these vehicles. The focus of this metric is on conventional charging methods, to better track and reflect automakers' progress in improving technology performance; we treat swapping as a form of mode innovation with a great deal of uncertainty rather than a technology improvement, and it is not a focus of this report.

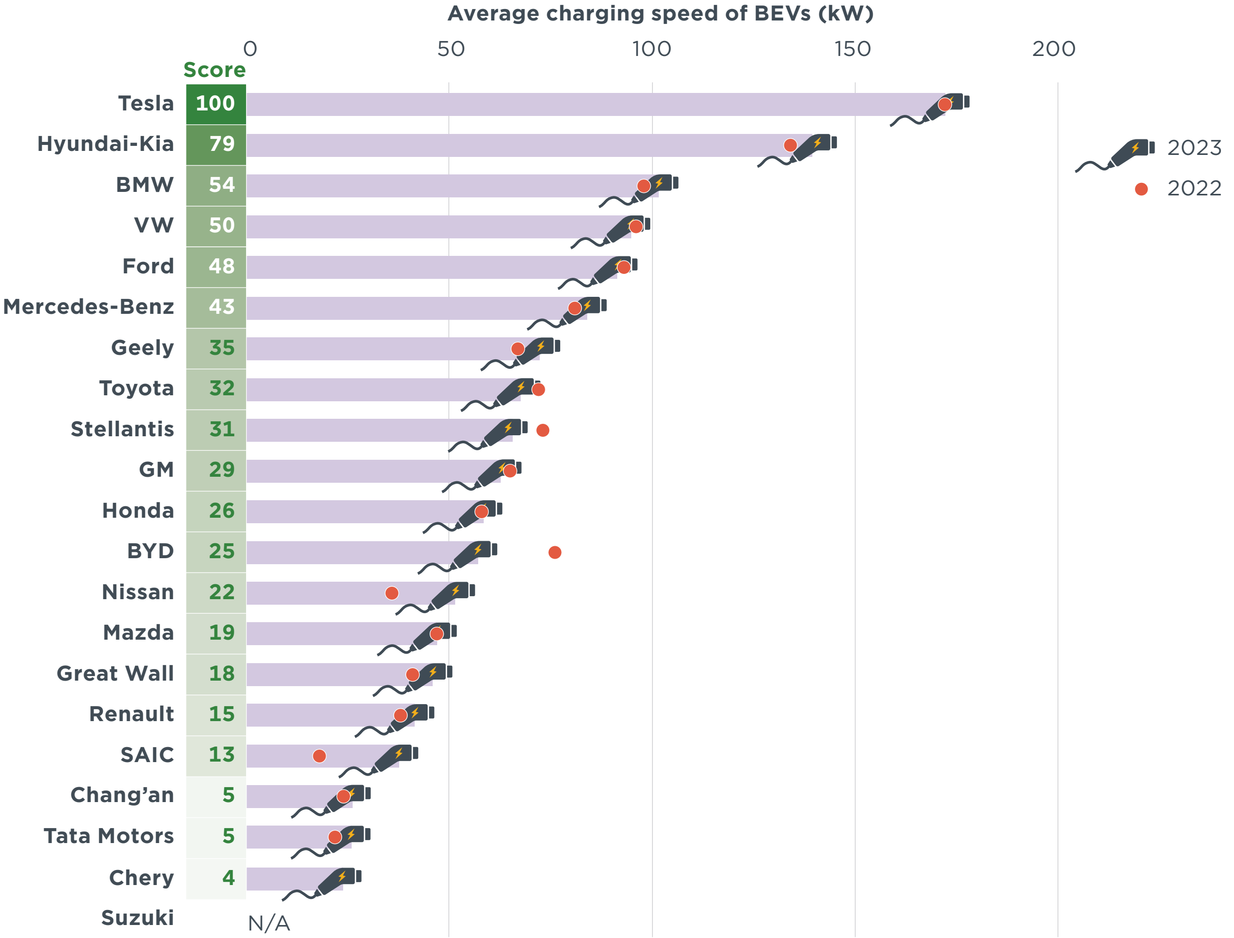
If a model has multiple charging options, we selected the average charging speed from the fastest option it allows. Then we averaged the maximum average charging speed of all BEV models of each manufacturer weighted by the sales of the models. Average charging speed values were converted to a 100-point score following Equation (1). The historical best performer of all reporting years, with the fastest charging speed, received a score of 100, and the historical worst performer with the slowest charging speed received a score of zero. Other manufacturers were scored based on their relative speed compared with the historical best and worst performers and received a score between zero and 100.

RESULTS

Automakers showed large variations in sales-weighted average charging speed, with the highest-scoring automaker charging 7 times faster, on average, than the lowest-scoring automaker. Figure 5 shows the final score and average charging speed for each manufacturer. Red dots show the corresponding 2022 value on this metric for each automaker. Table B3 in Appendix B details the sales-weighted average charging speeds for each automaker for BEVs that do not support fast charging and for BEVs that support fast charging, and includes the sales share of each BEV group for each manufacturer. The table also shows the score comparison between 2022 and 2023.

Figure 5

Average charging speed and metric score by manufacturer.



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Tesla still topped all manufacturers in charging speed for fast charging with an average charging speed of 172 kW. Hyundai-Kia followed with an average speed of 139 kW. Both Tesla and Hyundai-Kia had several high-selling models that were among the fastest-charging BEVs available, including the Tesla Model Y, Hyundai IONIQ 5, and Kia EV6.

SAIC, Chang'an, Tata Motors, and Chery recorded slower average charging speeds. SAIC's lower speed is partly because 41% of its BEVs did not support fast charging. Despite the fast-charging capability of more than 95% of BEVs from Chang'an, Tata Motors, and Chery, the average speeds for these manufacturers were much slower than the leaders. For example, Tata Motors' Xpres-T BEV requires 59 minutes to charge its 26-kWh battery from 0% to 80%, averaging around 21 kW. Chery had the lowest score with an average charging speed of 24 kW, mainly because its top-selling model—the Chery QQ Ice Cream, which accounted for 48% of its BEV sales—takes 75 minutes to charge its 17-kWh battery to 80%. Suzuki has no score for this metric, because it did not sell any BEVs in 2023.

Most manufacturers saw little change in their average charging speed from 2022 to 2023. Compared with 2022, SAIC and Nissan had the highest score increases, of more than 5 points, whereas BYD's scores fell by more than 5 points. In 2023, SAIC launched a new version of its best-seller, the Wuling Hongguang Mini, equipped for the first time with fast-charging capability, which significantly increased SAIC's fleet-average charging speed. The fluctuations in Nissan and BYD's charging speeds, meanwhile, largely resulted from shifts in their sales composition. Notably, in 2023, the sales share of Nissan's fastest-charging model, Nissan Ariya, rose to 31% from 9% in 2022. By contrast, BYD's newly introduced subcompact BYD Seagull, which was among the slowest-charging models in its offerings, achieved a 17% market share in 2023.

4.3 Driving range

Driving range is another metric valued by consumers, as longer range expands vehicle functionality and minimizes range anxiety. It is a key factor in the convenience of BEVs for consumers. Automakers that offer only shorter-range BEVs might struggle to keep up in the ZEV transition; research suggests consumers might be less likely to switch to EVs with short ranges (Stockkamp et al., 2021). In another sign of the importance of driving range, the California Air Resources Board (CARB) has set minimum range requirements for BEVs that can count toward the ZEV targets in its Advanced Clean Cars II regulation (CARB, 2022). Offering higher-range vehicles could encourage faster ZEV uptake, delivering more climate benefits as well as making automakers more competitive.

While consumers generally prefer a longer driving range, it comes with costs, both financial and environmental. According to Poupinha and Dornoff (2024), larger battery packs can increase energy consumption and total cost of ownership and contribute to higher GHG emissions compared with BEVs with smaller battery packs. There are costs for the manufacturer as well, because greater quantities of input materials such as lithium and other critical minerals are necessary to build the larger batteries. Designing BEVs with longer ranges can thus increase manufacturer exposure to price swings in lithium and other minerals compared to making short-range vehicles. Additionally, because battery production and mining are major sources of the overall GHG emissions resulting from BEV manufacturing, making longer-range vehicles will increase those emissions as long as fossil fuels are used in upstream mining and manufacturing.

Despite such considerations, we include this metric in our assessment because of the importance of driving range in attracting a wide consumer base. Additionally, as the vehicle market is still dominated by ICEVs, larger-battery BEVs still provide environmental benefits relative to conventional-fuel counterparts.

METHODOLOGY

The sales-weighted average driving range of ZEVs sold by each manufacturer was calculated after excluding models that sold fewer than 100 units in the six major markets. We first collected certified driving ranges in kilometers for each ZEV model in our vehicle database. This specification measures the maximum distance that a BEV can travel on a full charge without recharging, or that an FCEV can travel on a single tank of hydrogen without refueling.

Like energy consumption, the driving range of BEV models in the database was measured using different test cycles. We followed the same method to standardize the range values of different test cycles to WLTP-equivalent driving range using conversion factors. We applied a discount factor of 1.15 to convert the NEDC or CLTC range to its equivalent value under the WLTP test cycle. Similarly, a multiplier of 1.2 was used to convert the U.S. label values to their equivalent values under the WLTP test cycle (Yoney, 2022).

This data was then weighted based on the total sales of each model in the six major markets in 2023, resulting in a weighted average that reflects the typical driving range under laboratory testing. The average driving range of each manufacturer was then converted to a 100-point score following Equation (1). The historical best performer, with the longest sales-weighted average range, received a score of 100, and the historical worst performer, with the shortest average range, received a score of zero. Other manufacturers were scored based on their relative driving range compared with the historical best and worst performers and received a score between zero and 100.

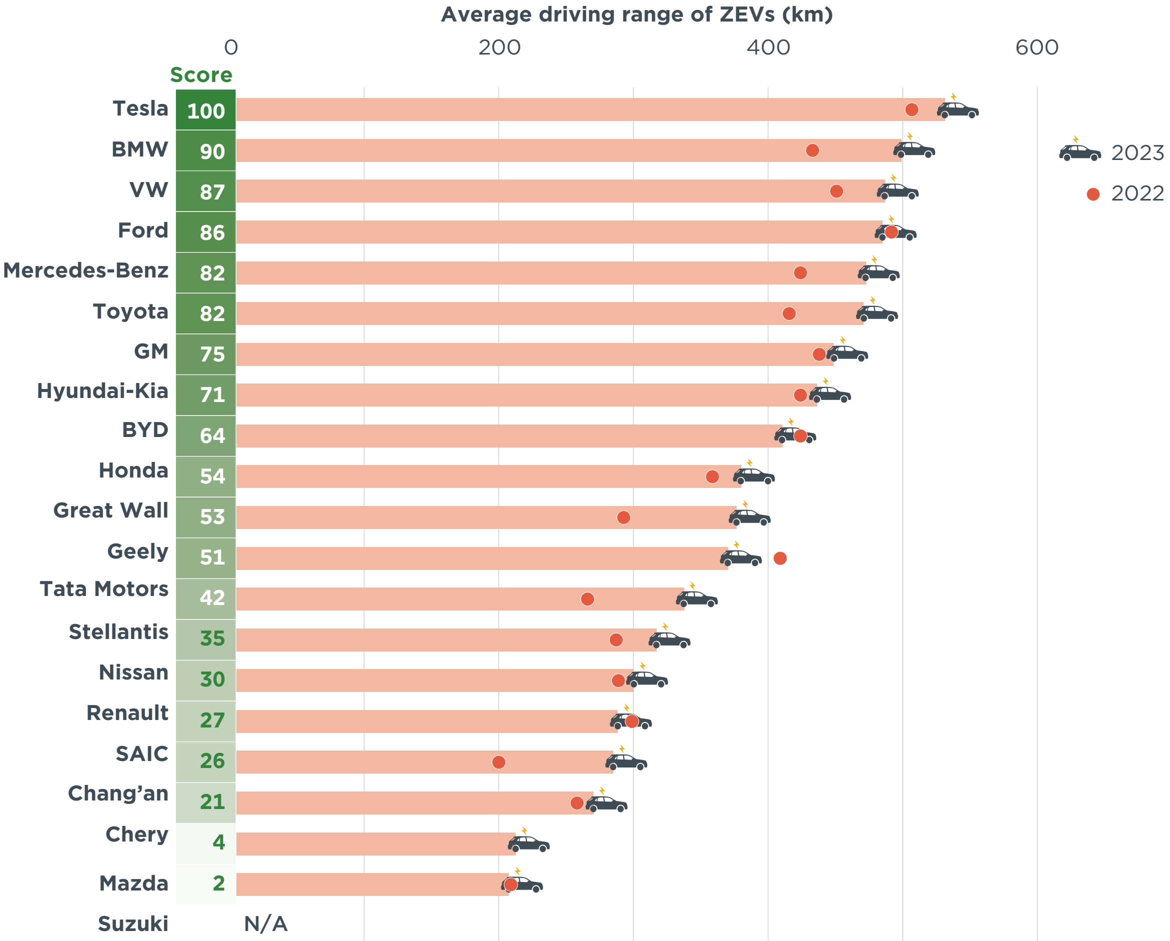
There is some overlap between the energy consumption metric and the driving range metric, because the efficiency of a vehicle is a key determinant of its driving range. However, it is important to consider both metrics in this assessment, because both aspects are important to the consumer experience: efficiency is a major factor in recharging costs and driving range affects the convenience of driving BEVs.

RESULTS

Average driving range varied greatly among the 21 manufacturers, from 203 km (Mazda) on the low end to 527 km (Tesla) on the high end. Fourteen manufacturers had an increase in their fleet-average driving range, with the average driving range across all manufacturers increasing from 395 km in 2022 to 419 km in 2023. Figure 6 shows the final score for each manufacturer and the average driving range of their ZEV models. Red dots show the corresponding 2022 value of this metric for each automaker. Score comparisons between 2022 and 2023 are shown in Appendix B, Table B4.

Figure 6

Fleet-average driving range of ZEVs and metric score by manufacturer.



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As noted above, Tesla continued to lead with an average driving range of 527 km. Compared with 2022, SAIC, Great Wall, Tata Motors, BMW, and Toyota increased their metric scores by more than 10 points, owing to a higher sales share of models with longer ranges. For example, in 2023, SAIC launched a longer-range (323 km) subcompact, the Wuling Bingo, which quickly became the second best-seller with a 29% market share.

Three manufacturers, Geely, BYD, and Ford, saw their scores decline by more than five points. Decreases in range for Geely and BYD were largely attributed to the popularity of their mini/subcompact BEV models. The Geely Panda Mini BEV, which has a range of 174 km, became Geely's best-selling model in 2023, while the BYD Seagull, a newly introduced subcompact car that is among the lowest-range models in its passenger car offerings (with a range of 309 km) achieved a 17% market share in 2023. Ford's reduction in range was primarily due to the rapid increase in market share of its new LCV model, the Ford E-Transit, which has a relatively shorter range (317 km) compared to its best-selling model, the Ford Mustang Mach-E BEV (540 km), which in turn saw a decline in market share in 2023. Given Ford had only four BEV models available to the market as of 2023, the change in market share of any model greatly impacted fleet average characteristics.

4.4 Renewable energy in manufacturing

Renewable energy in manufacturing reflects efforts to decarbonize manufacturing operations. With the transition from ICEVs to ZEVs, the relative importance of GHG emissions from manufacturing activities will increase and become a necessary area of focus in decarbonizing the industry. The renewable energy in manufacturing metric specifically evaluates energy use in vehicle production and battery production because the latter is the most energy-consuming part of the upstream ZEV supply chain. Upstream emissions associated with material sourcing are not accounted for in this metric given limited information on manufacturers' efforts to source low-emission materials.

METHODOLOGY

The evaluation of manufacturing decarbonization is based on two factors: renewable electricity in vehicle assembly and renewable electricity in battery production. Every manufacturer received a score for each of these two factors, the average of which provided the final score for this metric. The two factors have the same weight, because estimates using the GREET model show that vehicle and battery manufacturing contribute similar levels of production emissions (Argonne National Laboratory, 2022).

a. Renewable electricity use in vehicle manufacturing and assembly

A manufacturer received 1 point if it used 100% renewable electricity in all plants within a market and zero points otherwise. The final point value is the sales-weighted average of points across the six major markets.

We only awarded credit to manufacturers that exhibited a commitment to 100% renewable electricity, because manufacturers in most markets can achieve 100% renewable electricity by purchasing renewable energy certificates. We did not award credit to manufacturers for the average share of renewables in the electricity they consume, because this often simply reflects the renewable share of the electric grid in that market and does not necessarily reflect any effort on the part of the automaker. For example, renewable electricity accounted for approximately 41% of gross electricity consumption in Europe in 2022 (European Commission, 2023). In the United States and Japan, renewable electricity constituted approximately 21% and 23%, respectively, of all electricity generation in 2023 (U.S. Energy Information Administration, 2024; Institute for Sustainable Energy Policies, 2023).

Some manufacturers, including some based in China, have built or are building on-site renewable energy generation capacity. However, the power generation capacity of these renewable energy projects is minimal compared with total manufacturing electricity use. These do not qualify for points based on the established criteria.

b. Renewable electricity use in battery production

A manufacturer received 1 point if it used 100% renewable electricity at its battery plants, assuming it had any battery plants, and if it required all battery suppliers to use 100% renewable electricity. Zero points were awarded otherwise.

Although some manufacturers are building their own battery production capacities, almost all manufacturers in this report rely on battery suppliers for ZEV production. Therefore, evaluating decarbonization efforts requires considering not only the renewable electricity used at manufacturers' own battery plants but also that used by the battery providers, which the manufacturers can influence through procurement requirements.

Fossil fuels such as natural gas are sometimes used as direct energy inputs (other than electricity) in the vehicle production process, but we did not account for fossil fuel use in this report because we found no evidence of any of the manufacturers phasing out fossil fuel inputs at either vehicle or battery production sites. We plan to start incorporating manufacturing fossil fuel phase outs in this metric in the future when automakers begin to make progress on that front.

After averaging the scores from (a) and (b), we converted the combined raw point value to a 100-point scale using Equation (1). We identified the historical best and worst performers from reporting years 2022 and 2023, assigning them scores of 100 and zero, respectively. Per Equation (1), manufacturers were scored based on their performance relative to these historical best and worst performers.

RESULTS

BMW, Mercedes-Benz, and VW led this metric in 2023, progressing far ahead of the other manufacturers. Mercedes-Benz was the only manufacturer with an improved score in this metric in 2023 compared with 2022, and it has moved to require all battery suppliers to be carbon neutral with an emphasis on using 100% renewable energy. Table 2 presents information on manufacturers' renewable electricity use at vehicle and battery production plants and indicates whether there is a renewable electricity requirement for battery suppliers; to the right, 2023 scores are compared against 2022 results. Cells highlighted in light yellow represent efforts that received credit based on our scoring methodology explained above.

Table 2

Use of renewable electricity for vehicle and battery production and metric score by manufacturer.

OEM	Renewable electricity use at vehicle and battery production plants[a]		Renewable electricity use by battery suppliers		Global score 2023	Global score 2022	Score changes
	Share of electricity that is renewable	Scope of production plants	Source batteries from suppliers?	Require suppliers to use renewable electricity?			
BMW	100%	Global plants	Yes	Yes	100	100	0
Mercedes-Benz	100%	Global plants	Yes	Yes	100	50	50
VW	56%	Global plants	Yes	Yes	73	75	-2
	100%	All plants in the European Union					
	100%	17 non-EU plants					
Ford	51%	Global plants	Yes	No	14	14	0
	100%	All plants in Europe					
Hyundai-Kia	100%	All plants in the European Union	Yes	No	11	11	0
Geely	60% (Geely)	Global plants	Yes	No	7	9	-2
	100% (Volvo Cars)	All plants in the European Union					
Tata Motors	26% (Tata Motors)	Global plants	Yes	No	7	6	1
	100% (JLR)	All plants in Europe					
Toyota	20%	Global plants	Yes	No	6	6	0
	100%	All plants in the European Union					
	100%	Several plants in South America					
GM	39%	Global plants	Yes	No	0	0	0
Stellantis	29%	Global plants	Yes	No	0	0	0
	100%	Several plants in the European Union and South America					
Honda	22%	Global plants	Yes	No	0	0	0
Suzuki	70,914 MWh	Plants in Japan and India	Yes	No	0	0	0
Nissan	8%	Global plants	Yes	No	0	0	0
Chang'an	37,672 MWh	Plants in China	Yes	No	0	0	0
BYD	44,000 MWh	Plants in China	No	No	0	0	0
Renault	56%	Global plants	Yes	No	0	0	0
	100%	Plant in Brazil, Colombia, Morocco, Romania, and Spain					
Tesla	25%	Global plants	Yes	No	0	0	0
SAIC	276 MWh	Plants in China	Yes	No	0	0	0
Great Wall	22%	Plants in China	Yes	No	0	0	0
Mazda	4,190 MWh	Plants in Japan	Yes	No	0	0	0
Chery	N/A	Plants in China	Yes	No	0	N/A	N/A

[a] Cells in yellow indicate 100% renewable electricity use of all the manufacturer's plants in one of the six major markets or all plants globally.

None of the manufacturers significantly progressed toward 100% renewable electricity use in their manufacturing sites. Based on our methodology, this warranted no score changes for manufacturers except minor shifts due to the change in relative sales by region from the previous year. BMW and Mercedes-Benz continued to use 100% externally purchased renewable electricity at their global production sites. For VW, the electricity consumed across all its EU sites was supplied with 100% renewable energy in 2023. Therefore, VW received credit for reaching 100% renewable electricity in the European Union, its largest market.

Some manufacturers, such as Ford, Hyundai-Kia, Geely, Tata Motors, and Toyota, were given partial credit for using 100% renewable electricity in their vehicle production sites in Europe, which make up between 13% and 29% of their sales. However, no progress was observed in other regions.

Although none of the remaining manufacturers met the criteria of using 100% renewable electricity manufacturing and assembling in any region, some made progress over the past year, increasing their renewable electricity share across global production sites. For example, by installing more new power generation facilities, Honda's renewable electricity share increased to approximately 22% in fiscal year 2023, from 12% in fiscal year 2022; Suzuki, for its part, is expanding solar power generation in Japan and India, its two largest markets. Such progress could be attributable to a combination of manufacturers' efforts to use renewable electricity and the natural progression of renewable electricity available from the grid. In general, however, manufacturers need to take stronger action to fully transition to 100% renewable electricity across all manufacturing sites worldwide.

As noted above, Mercedes-Benz was the only manufacturer awarded additional points in 2023 for requiring all battery suppliers to have carbon-neutral production with an emphasis on using 100% renewable electricity. Although Volvo Cars (owned by Geely) also has contracts with two of its battery cell partners that require carbon-neutral production of batteries, Volvo Cars was not credited for this, because the requirement does not apply to all battery providers. For other automakers, efforts to require battery suppliers to decarbonize production, specifically by using renewable electricity, were still lacking.

Some manufacturers undertook broader efforts to decarbonize their supply chains, including by conducting supplier GHG emission assessments or requiring carbon emission reduction plans (with no specific requirement on the use of renewable electricity), or made soft obligations to increase renewable energy usage in their production. For example, Tesla requires emission data collection from its suppliers, while Hyundai conducts investigations of key suppliers and reviews emission reduction plans but has no specific requirements for the use of renewable electricity in their battery production. Additionally, Geely stated that it has encouraged its main battery suppliers to increase the proportion of renewable energy in cell production with no details of requirements or guidelines for its suppliers.

4.5 Battery recycling and repurposing

Increased ZEV production means increasing demand for raw materials used to produce batteries and thereby increasing the share of emissions from battery material sourcing, extraction, and processing. Battery recycling and repurposing can reduce the demand for raw materials by recovering critical materials to produce new batteries or reusing batteries for second-life applications.

A well-established battery recycling system allows for the recovery and reuse of valuable materials such as lithium, cobalt, and nickel from retired batteries to produce new batteries, reducing the need for new raw materials and the emissions from their extraction and processing. Battery repurposing involves reusing batteries at the end of their useful first life in other applications, such as for backup power or electricity storage for factories, reducing the need for new battery production and associated emissions. Electricity consumption and emissions from the grid can also be decreased by integrating repurposed batteries as energy storage in renewable energy installments like solar panels at vehicle manufacturing facilities.

We expect automakers to increasingly incorporate battery recycling into their manufacturing supply chains as the ZEV market grows. In addition to reducing upstream manufacturing emissions, battery recycling can directly reduce automaker costs by avoiding the need to source as much new raw material. Furthermore, battery recycling can to some extent insulate automakers from fluctuations in raw material prices.

METHODOLOGY

A manufacturer received 1 point for having either battery recycling or repurposing projects in a given market, or zero points otherwise. The final score is the sales-weighted average of points across the six markets analyzed. We converted these final scores to a 100-point scale using Equation (1). The manufacturer with the historical best performance received a score of 100 and the historical worst received a score of zero. Other manufacturers were scored based on their relative points on the metric compared with the historical best and worst performers.

We did not differentiate recycling projects based on the recycling capacity or repurposing scale. While sales of new EVs continue to ramp up, the volume of end-of-life batteries from EVs that can be recycled remains low, with most recycling related to production scrap. Therefore, there is still insufficient information to compare recycling capacities and the emissions-reduction impact of those efforts. Nevertheless, we observe that manufacturers are at various phases in implementing their announced projects, and will consider differentiating the progress of manufacturers' implementation of those announced projects in the future.

RESULTS

In 2023, most manufacturers were planning battery recycling or repurposing projects; some projects were more advanced than others. Four manufacturers (Mercedes-Benz, VW, and Honda) expanded pilot projects into more markets, and Chang'an started a project in its home market, although they were still in the early phases. Table 3 summarizes auto manufacturers' battery recycling and repurposing efforts across the six markets through 2023. The  symbol indicates that a manufacturer had a battery recycling system project and a  symbol indicates that a manufacturer had a battery repurposing project. The table also shows the market share of LDVs in the markets where manufacturers have deployed battery recycling or repurposing projects and the final score after rescaling. A cell with market share but without any symbol means the manufacturer has no battery recycling or repurposing project in that market.

Table 3

Manufacturers' battery recycling- and repurposing-related actions by market as of 2023, with the market's percentage of total LDV sales for each automaker and the score comparison with the 2022 report.

OEM	China	U.S.	Europe	Japan	India	Korea	2023 score	2022 score	Score changes
Chang'an	♻ 100%						100	0	100
Tesla	♻ 37%	♻ 40%	♻ 22%				100	100	0
Hyundai-Kia	♻ 🛢 6%	♻ 🛢 33%	♻ 🛢 22%	♻ 🛢 <1%	♻ 🛢 17%	♻ 🛢 23%	100	100	0
Chery	♻ 🛢 100%						100	N/A	N/A
BYD	♻ 🛢 100%			<1%	<1%		100	100	0
Great Wall	♻ 100%		<1%				100	100	0
Stellantis	♻ 2%	♻ 🛢 35%	♻ 🛢 62%	<1%	<1%	<1%	99	98	1
Geely	♻ 🛢 76%	♻ 🛢 7%	♻ 🛢 16%	♻ 🛢 1%	♻ 🛢 <1%	♻ 🛢 1%	98	100	-2
VW	🛢 42%	♻ 8%	♻ 47%	1%	1%	1%	97	48	49
Renault	<1%		♻ 🛢 95%	<1%	3%	1%	95	90	5
Mercedes-Benz	♻ 37%	♻ 16%	♻ 🛢 41%	2%	1%	3%	93	43	50
BMW	♻ 🛢 36%	♻ 🛢 17%	♻ 🛢 40%	2%	<1%	4%	93	92	1
Ford	8%	♻ 64%	♻ 28%	<1%		<1%	92	91	1
SAIC	♻ 🛢 83%		14%	<1%	3%		83	90	-7
Tata Motors	10%	7%	♻ 🛢 14%	1%	♻ 68%	<1%	81	88	-7
GM	25%	♻ 🛢 74%	<1%	<1%		1%	74	99	-25
Toyota	25%	♻ 30%	13%	♻ 🛢 30%	3%	<1%	59	59	0
Honda	37%	♻ 40%	♻ 🛢 2%	18%	3%	<1%	42	32	10
Nissan	28%	37%	🛢 13%	🛢 20%	1%		33	31	2
Suzuki			8%	25%	67%		0	0	0
Mazda	11%	45%	23%	22%			0	0	0

♻ = recycling 🛢 = repurposing

Chang'an, Tesla, Hyundai-Kia, Chery, BYD, and Great Wall led this metric, with projects such as in-house recycling facilities, strategic partnerships, and investments with battery companies in their dominant markets.

Chang'an's score substantially increased following its announcement of a partnership with Ganfeng Lithium, a lithium producer in China. Their memorandum of understanding (MOU) lays out cooperation in upstream and downstream processes, including the recycling of used lithium batteries. Tesla is advancing its recycling activities through on-site recycling facilities, the development of scalable battery recycling technology for nickel- and iron-based cathode chemistries and re-use of lithium, and ongoing partnerships with recycling companies in the United States and China.

Hyundai-Kia partnered with Hyundai GLOVIS and Hyundai MOBIS for a global battery collection network and remanufacturing business. Chery partnered with Guanghua Technology and invested in Anhui Jiaqi Energy Technology Co., a subsidiary of Chery, to recycle and repurpose used EV batteries. BYD continued to operate battery recycling outlets across China and implemented repurposing projects in collaboration with Chinese recycling company GEM Co Ltd and Japanese trading company ITOCHU

Corporation for second-life applications such as energy storage systems for renewable energy facilities. Great Wall has operated nearly 200 battery recycling sites partnering with 45 dealerships and has established a joint venture through its subsidiary, Honeycomb Energy, to recycle lithium batteries. That joint venture is expected to begin operation in 2024.

Some manufacturers, such as Mercedes-Benz and VW, received higher scores because they expanded pilot projects beyond their home markets. Mercedes-Benz, for example, is increasing recycling efforts in China and the United States—which together made up 52% of its LDV sales in 2023—following a recycling project in Kuppenheim, Germany. In February 2023, the automaker signed an MOU with GEM and Hunan Bangpu to build a closed-loop battery recycling system in China that will be resupplied to CATL, Mercedes-Benz's battery supplier.

Similarly, VW expanded its efforts in the United States, where it entered into a partnership with Redwood Materials to recycle Volkswagen and Audi EV batteries, and in China, to repurpose batteries for energy storage systems in partnership with Huayou Recycling. VW also entered into a partnership with Umicore Group to further advance recycling efforts in Europe in addition to the ongoing recycling facility at its plant in Salzgitter, Germany. Other manufacturers, including Stellantis, Geely, Renault, BMW, Ford, SAIC, Tata Motors, and GM, scored well because they have announced relevant projects in their home markets.

Among Japan-based manufacturers, Toyota has recycling and repurposing operations in Japan and has established a partnership with Redwood Materials in the United States. Honda has a partnership with SNAM to recycle and develop second-life opportunities to repurpose EV batteries in Europe and with Ascend Elements in the United States. Nissan continued repurposing batteries for energy storage systems in Japan and the United Kingdom. Meanwhile, Mazda has established a battery collection and recycling mechanism for batteries employed in their hybrid vehicles in its home market, Japan, and Suzuki operates a recycling mechanism for hybrids both in Japan and abroad (India and Europe). However, we gave no credit for Mazda or Suzuki's efforts, because there is no clear indication that the adopted recycling technologies can be used for both battery types (nickel metal hydride used in hybrids and lithium-ion used in BEVs). Therefore, it is uncertain that the technologies can be used for recycling batteries from BEVs.

5

STRATEGIC VISION

5 STRATEGIC VISION

5.1 ZEV target

The ZEV target metric evaluates the ambition of a manufacturer in transitioning to a 100% ZEV fleet relative to the pace needed to meet the Paris Agreement. An ambitious target can demonstrate a manufacturer's commitment to complete and keep up with the ZEV transition. In contrast, a manufacturer without a target, or with a weak ICEV phase-out target, may be signaling it is less likely to invest in ZEV technologies in the near term. This metric is assessed by carefully reviewing and comparing manufacturers' announcements on their ZEV goals.

METHODOLOGY

The primary sources of ZEV target information are manufacturers' sustainability reports, announcements, press releases, and news articles available as of the end of 2023. Several manufacturers announced electrification targets pertaining to all or some of their fleets over the next decade or two. These targets vary in several ways, including the time frame (2025, 2030, or 2035), geographical coverage (global or regional), segments covered (PCs only, or all LDVs), and technology types (only ZEVs, or ZEVs and PHEVs).

We set the same benchmark as in the previous report for ZEV targets in the six major markets, at 77% by 2030 and 97% by 2035, as these are the levels of ZEV sales our modeling has found would be necessary in the leading markets to keep us on track to meet Paris Agreement goals (Sen & Miller, 2023).[5] We derived the ZEV target score by calculating the ratio of the manufacturer's ZEV sales target to its corresponding benchmark: that is, a ZEV target for 2030 was compared with the 2030 benchmark and a ZEV target for 2035 was compared with the 2035 benchmark. In cases where manufacturers only had a target for 2025, which was mainly the case for China-based manufacturers, we compared that target against the 2030 benchmark and assumed the ZEV market share will not grow beyond 2025 in the absence of a longer-term target for 2030 or 2035. The ratio of the ZEV sales target to the benchmark can be larger than 100% if the manufacturer has a more ambitious target than the benchmark. For example, GM received a target score of 103% after its 2035 target of 100% ZEVs was benchmarked to the 2035 ZEV target of 97%. Tesla received a maximum score of 100 for already producing 100% ZEVs. BYD, although it produced 100% EVs, received a partial score based on its ZEV-equivalent sale share as it still produces PHEVs and has not announced a target for phasing them out.

New in this iteration, we averaged the scores of the mid-term 2030 and long-term 2035 targets in cases where an automaker had both. In our 2022 rating, we only took the higher score of the two; in that study, the long-term targets were always the more ambitious relative to their benchmarks. We made this methodological change to reflect changing signals from manufacturers, some of which reduced the ambition of their 2030 targets in 2023 compared to what they had announced in 2022. All manufacturers that announced 2035 targets also have set 2030 targets, so this revised methodology allowed us to account for the less ambitious 2030 targets for all automakers.

Some manufacturers had multiple ZEV targets with different scopes, applying to certain regions, subsidiary brands, and vehicle types (i.e., only PCs or all LDVs).

5 Major markets in the analysis included China and the members of the ZEV Transition Council (Canada, Denmark, the European Commission, France, Germany, India, Italy, Japan, Mexico, Netherlands, Norway, Spain, South Korea, Sweden United Kingdom, and the United States).

For each automaker, we calculated the sales-weighted average score based on the vehicle sales in each target scope. Some automakers' announcements of ZEV targets were worded generally to apply to sales in "the leading markets." We assumed that this included all six regions investigated in this analysis unless a different scope was clarified in the automaker's statement. Then, we calculated the sales-weighted average score of the different targets, if any, for each manufacturer.

We considered BEVs, FCEVs, and the ZEV-equivalent portion of PHEVs when calculating the ZEV targets. Although most manufacturers set their targets for only ZEVs, some manufacturers, notably those based in China, had only announced EV targets that included both BEVs and PHEVs, and the split was not specified. For these manufacturers, we discounted the EV targets for the PHEV share of their 2023 total EV sales based on real-world data on the electric driving share of PHEVs, following the methodology we used to calculate the ZEV-equivalent sales share in Section 3.1. For instance, Great Wall set an EV target of 80% by 2025 and has a ratio of 0.74 between its ZEV-equivalent sales and total EV sales in 2023. Therefore, we multiplied 80% by 0.74 to obtain a 59% ZEV-equivalent target.

Targets that included conventional (non-plug-in) hybrid vehicles as a ZEV target were not considered in the scoring because conventional hybrid vehicles cannot be recharged with electricity and thus there is no zero-emission component to their operation. Furthermore, an electrification target that includes hybrids could potentially be dominated by hybrids, without any guarantee of the automaker investing in a ZEV future.

We converted the ZEV target ratios to a 100-point scale using Equation (1). The change in methodology to account for weaker 2030 targets reduced the scores for many automakers. To prevent this methodological change from reducing automaker scores across the board, we re-calculated the scores from our 2022 rating using this revised methodology to identify the historical best and worst performers in 2022 and 2023. We then assigned a score of 100 to the historical best performer and zero to the historical worst performer of this metric. Per Equation (1), manufacturers' ZEV targets were scored relative to the historical best and worst performers.

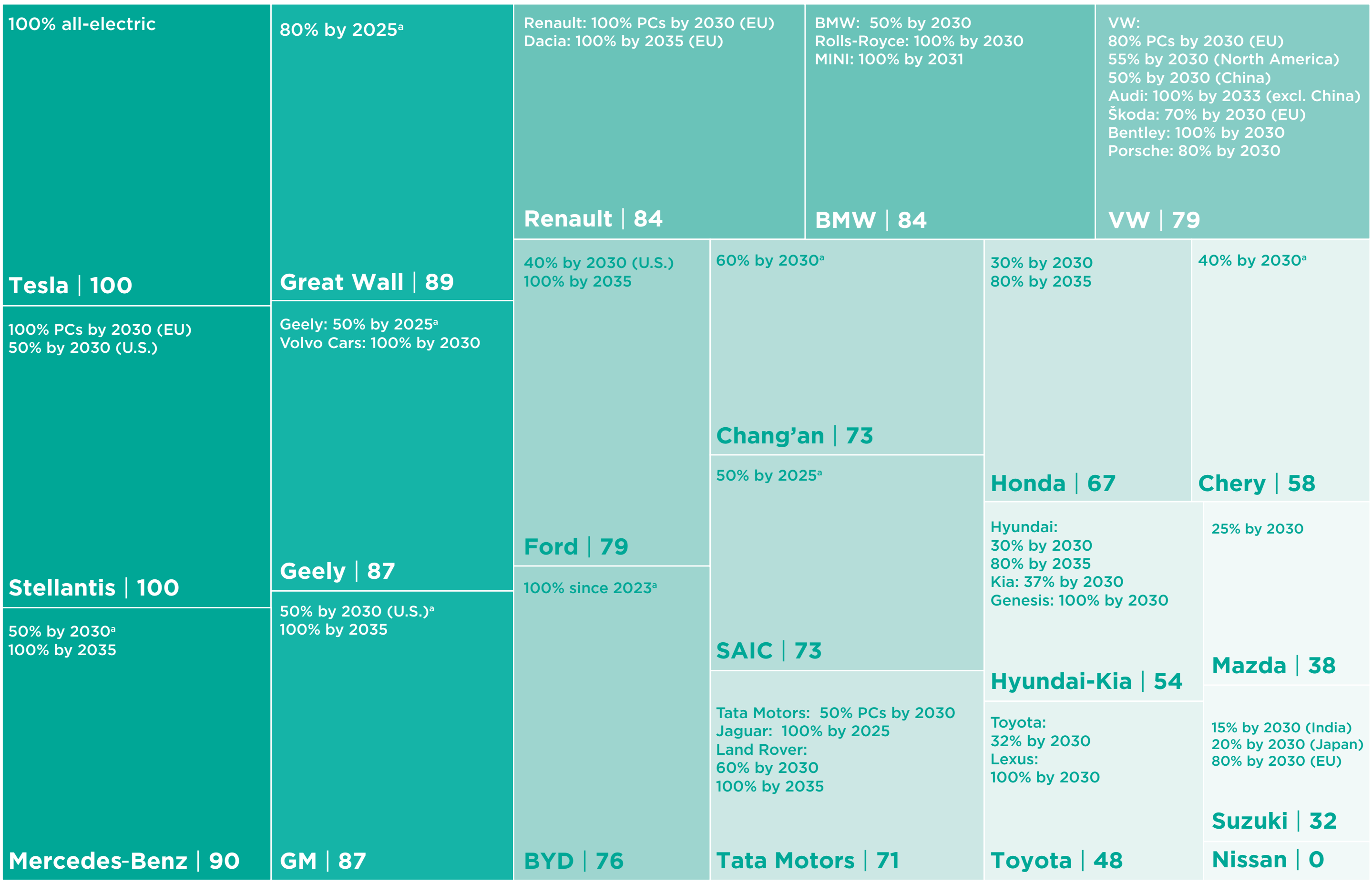
RESULTS

By the end of 2023, nine automakers had 100% ZEV targets for at least one brand in leading markets. Besides Tesla, which already produces and sells only ZEVs, Jaguar (Tata Motors) had a 100% ZEV target for 2025, and Rolls-Royce (BMW), Volvo Cars (Geely), Genesis (Hyundai), Lexus (Toyota)[6], and Bentley (VW) all had 100% ZEV targets for 2030. MINI (BMW) had a 100% ZEV target for 2031, Audi (VW) had 100% by 2033, and GM, Ford, Mercedes-Benz and Jaguar Land Rover (JLR, Tata Motors) had a 100% ZEV target for 2035. Figure 7 summarizes the ZEV sales targets for each auto manufacturer at the global and regional levels, including the targeted market share, target year, vehicle technology, vehicle segment, and the final score for the ZEV target metric after rescaling. Table B5 in Appendix B further details the score changes and the comparison between 2023 and 2022 scores adjusted to the new methodology.

6 Toyota-Lexus's 100% ZEV target in North America, China, and Europe by 2030 is not shown in Table 4. Toyota's score is based on Toyota's corporate-level target because it results in a better score for Toyota.

Figure 7

Announced EV sales targets and metric score by manufacturer.



[a] ZEV target includes plug-in hybrid electric vehicles; PCs: passenger cars

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Stellantis led among conventional manufacturers that still produce ICEVs, with a commitment to transition to 100% ZEVs for passenger cars in Europe and 50% for new light-duty vehicles in the United States by 2030. These two markets accounted for 97% of Stellantis' LDV sales in 2023.

Compared to last year, seven manufacturers bolstered their targets. Geely raised its global 2025 EV target from 40% to 50% and SAIC increased its 2025 EV target from 32% to 50%. VW increased the 2030 ZEV targets for its VW brand in key markets—from 70% to 80% for passenger cars in Europe and 50% to 55% for LDVs in the United States—while maintaining its 2030 target for China of at least 50% ZEV. Targets for other VW brands, including Audi, Škoda, Bentley, and Porsche, were unchanged in 2023. BMW moved its global ZEV target of 100% for MINI from the early 2030s to a clearly indicated target year of 2031. Under Hyundai-Kia, Kia increased the global 2030 ZEV target of 37% from 30% and Genesis aims for a global 2030 ZEV target of 100%. Tata Motors brand increased its 2030 ZEV target from 30% to 50% while Suzuki, which had no ZEV targets in 2022, announced 2030 ZEV targets in Japan (20%) and two key overseas markets, India (15%) and Europe (80%).

Under our revised methodology, the scores of several automakers with both 2030 and 2035 targets dropped. GM, Ford, and Mercedes-Benz remain committed to a 2035 target of 100% for LDVs in leading markets as signatories of the Zero Emission Vehicles Declaration ("ZEV Declaration," 2021). However, their 2030 targets are less ambitious compared to the 77% ZEV sales benchmark: Ford aims to reach between 40-50% zero-emission vehicles in the U.S; Mercedes-Benz aims to achieve a 50% EV target that includes PHEVs, where market condition allows; and GM aims to achieve a 50% EV target that includes PHEVs in the U.S. market. Although Nissan increased its 2026 target from 40% to 44%, the target includes e-Power hybrid models that run on 100% gasoline; Nissan, therefore, received a score of zero.

Three manufacturers rolled back the ambition of their mid-term targets. Mercedes-Benz revised its target from a 2025 EV (including PHEV) target of 50%, where market conditions allow, to a 2030 EV target of 50% for passenger cars, a 5-year delay. Ford no longer has a 2030 global ZEV target of 50% and revised the 2030 U.S. target from 50% to 40%–50%. Renault's score declined from 2022 because it narrowed the scope of its 2030 ZEV target of 100% for the Renault brand in Europe from all LDVs to only passenger cars. Pulling back on ZEV targets can signal uncertainty to consumers and raise concerns among investors and business partners regarding an automaker's commitment and preparedness to fully transition to ZEVs in the long term.

While other manufacturers, including Mazda and Chang'an, showed no shifts in their targets compared to 2022, scores may have changed due to the PHEV adjustments and the distribution of sales among brands. Toyota announced an interim global sales target of 1.5 million ZEVs by 2026, although this target was not more ambitious than its 3.5 million ZEVs sales target by 2030.[7]

In addition, we observed that some manufacturers are far behind their near-term targets. For instance, Great Wall, whose EV sales accounted for 17% of its sales in 2023, will have to rapidly accelerate progress to meet its 2025 target of 80%. Similarly, Jaguar (owned by Tata Motors), with an EV sales share of approximately 15%, is well below its 2025 target of 100%. Although manufacturers still received a score in this report for having set those targets, their scores will drop in future evaluations if they fall short of announcements.

5.2 ZEV investment

ZEV investment is a measure of a manufacturer's financial commitment to the transition to zero-emission technology. While investment commitments do not by themselves guarantee the ZEV transition, they are an indication of commitment and planning on the part of automakers. Investing in ZEVs now reduces the risk that automakers will fall behind in the transition.

METHODOLOGY

This metric evaluates a manufacturer's investment in the ZEV transition. We consider research and development expenditure, capital expenditure on ZEV production sites to increase manufacturing capacity and construction of ZEV supporting infrastructure like battery plants, charging stations, and establishment of the broader charging network. We also consider financial outlays for other actions like establishing subsidiaries, joint ventures, and partnerships. In this iteration of the rating, we also collected investment announcements in raw materials that are used to produce batteries for EVs, such as lithium, cobalt, nickel, and manganese. The supply of these minerals will need to scale up to meet global EV battery demand as the ZEV transition continues, and directly investing in mineral production now may reduce supply chain risk and price exposure for automakers.

7 To infer Toyota's 2030 target from this goal, we estimated the company's global LDV sales in 2030 based on its 2023 global LDV production and an annual growth rate of 2.2% (the compounded annual growth rate of Toyota's global production from 2011–2023) and the Lexus brand's 100% ZEV target by 2030 in North America, China, and Europe.

Our primary source of investment data was the Atlas EV Hub, an online database developed by Atlas Public Policy (2023). The database documents EV investments announced by major manufacturers worldwide from 2016 to 2023. We also collected additional investment information from sustainability reports and official press releases to verify Atlas EV Hub data and update the investment data when discrepancies were found. We used information that was verified by manufacturers, such as the percentage of capital expenditure that is allocated for EV investment. We collected information on both the monetary amount and the investment period for ZEV investments that were announced from 2016 to 2023.

Some manufacturers announced EV investments in combination with other advanced vehicle technologies such as smart transportation or autonomous driving technology. In these cases, we derived the EV investment amount either from the EV-specific portion that the manufacturers provided or by splitting the investment amount equally between the different types of technologies named.

The total investment was evaluated in terms of 2023 U.S. dollars per vehicle. We used cumulative investment amount as the financial measure given that investments are made over varying timeframes. We adjusted for the time value of money by using a discount rate of 3.2%, based on the average of annual inflation rates between 2016 and 2023 calculated by the Organization for Economic Co-operation and Development (Organization for Economic Co-operation and Development, 2023). We first distributed each announced investment evenly across the announced period to generate a stream of annualized investment. In the absence of stated duration, we assumed an investment period of 10 years given the transitional nature of the current ZEV market, which requires a longer recovery period for investments than would be expected in a more mature market. The investment amount of each year was adjusted to 2023 U.S. dollars. Then we summed up the present values of these annualized investments to generate the cumulative investment amount in 2023 dollars.

Furthermore, investment announcements typically do not specify the investment split between different powertrains, for example BEVs and PHEVs. To reflect the ZEV investment amount manufacturers are committed to, like the ZEV target metric, we consider BEVs, FCEVs, and the ZEV-equivalent portion of PHEVs when calculating the ZEV investment. We adjust their investments using the ratio between ZEV-equivalent share and the actual EV share of 2023, which is calculated and summarized in Section 3.1.

We then divided the cumulative investment amount in 2023 U.S. dollars by the product of the average LDV sales in the six major markets in 2022 and 2023 and the investment return period of 10 years to derive the investment per vehicle. We identified the historical best and worst performers from reporting years 2022[8] and 2023 and assigned them scores of 100 and zero, respectively. Per Equation (1), manufacturers' investment scores were awarded relative to the historical best and worst performers.

RESULTS

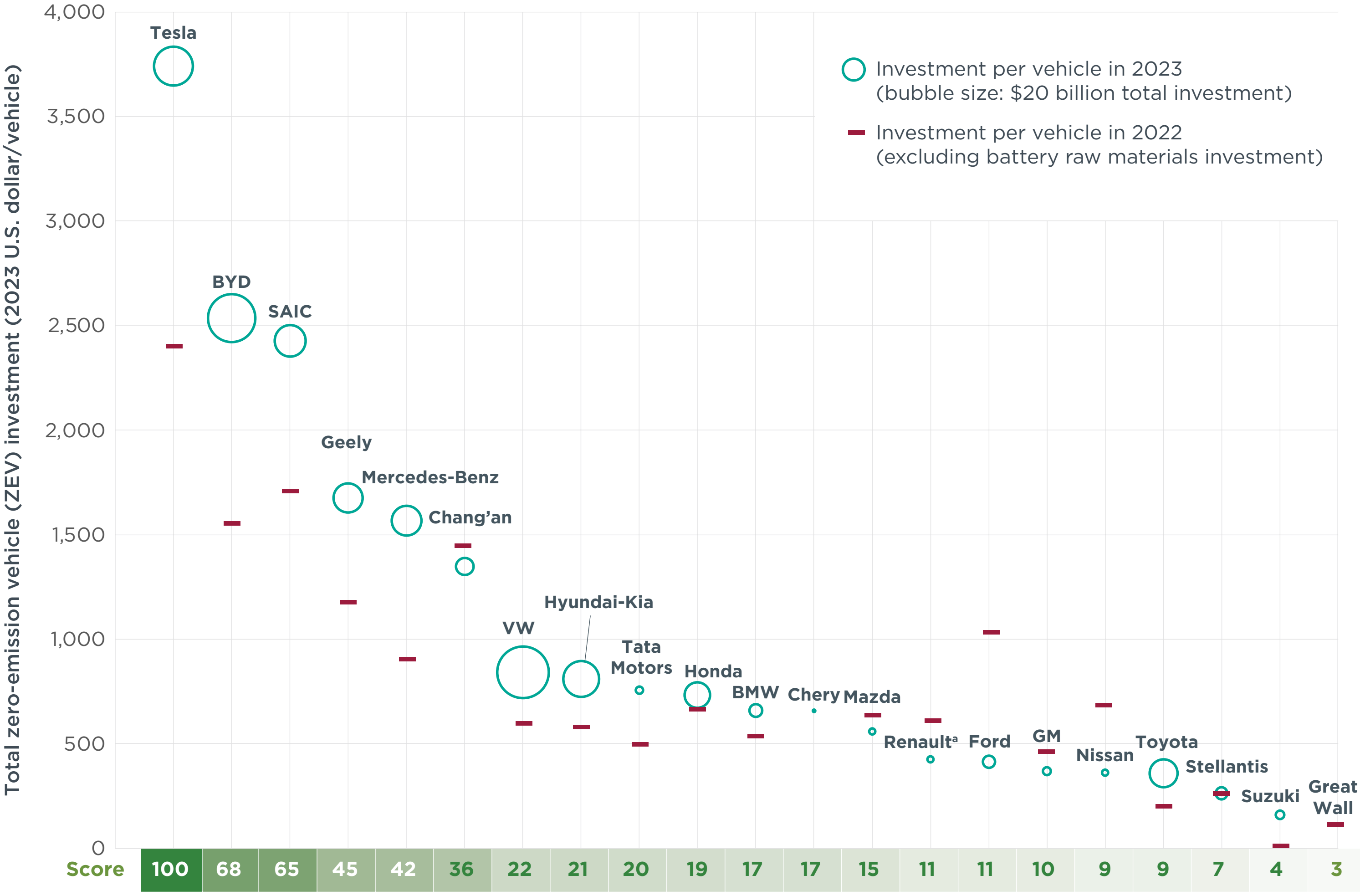
The announced financial commitments from automakers differed substantially in terms of per-vehicle investment values and cumulative investment values. Figure 8 shows the ZEV investment levels per vehicle in 2023 and 2022, with manufacturers arranged left to right from highest to lowest investment per vehicle in 2023. The bubble size reflects the extent of total investments announced by each manufacturer in 2023 U.S dollars.

8 To fairly compare the 2022 and 2023 investment per vehicle, we adjusted the 2022 investment per vehicle values to the 2023 U.S. dollar and applied the average sales to derive investment values comparable to the 2023 investment values.

The bars represent the 2022 per-vehicle investment by automakers for comparison.[9] Note that the 2022 investment does not include investments in battery raw materials by automakers, which is an element newly added to this report. Table B6 in Appendix B further details the cumulative EV investments announced by each manufacturer, the investment values in 2023 dollars, the investment in battery raw materials, the adjustment factor from EV to ZEV, and the comparison of investment per vehicle for 2023 and 2022.

Figure 8

Per-vehicle ZEV investment and metric scores by manufacturer.



[a] This number reflects the corrected 2022 investment per vehicle for Renault. The previous report overestimated Renault's investment due to a misinterpretation of the scope of the announced investment.

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In 2023, 13 automakers invested more in the ZEV transition compared to 2022. Tesla continues to lead in terms of investment per vehicle sold ($3,740) followed by China-based manufacturers BYD ($2,535) and SAIC ($2,427). These companies continued to ramp up EV production and invest both in their home markets and overseas. VW increased its investment and maintained the largest cumulative investment among all manufacturers. However, as the second largest LDV manufacturer in the world, VW's score for this metric is behind that of several others after taking the size of the company into account.

9 For fair comparison, the 2022 investment level has also been adjusted to reflect the same sales projections as in this report and is adjusted to 2023 dollar value.

Mercedes-Benz moved into the top half of the list due to larger EV investment announcements in 2023, resulting in a per-vehicle investment of $1,567; it scored high compared with other automakers headquartered in Europe with its $45 billion (€41 billion) investment commitments in EVs through 2030. Tata Motors also saw a jump in investment to $756 based on the latest announcement by JLR to accelerate electrification and other future technologies with an annual investment of $2.9 billion (£2.25 billion) over the next five years. Suzuki announced its first investment plan of approximately $14 billion dollars (¥2 trillion) in EVs through 2030. Although Suzuki still received a low score compared with other manufacturers for this metric, this announcement marked a big step for Suzuki to start investing in the ZEV transition.

Among the four largest automakers, VW and Hyundai-Kia were making higher investments per vehicle (between $800–$850) relative to Toyota and Stellantis. Toyota saw a score increase from 2022 as it announced EV investments throughout the year, including an $8 billion investment for the expansion of Toyota Battery Manufacturing in North Carolina.

The scores for GM, Ford, and Renault dropped from 2022 to 2023. Both GM and Ford reduced their announced investment amounts compared with what they announced in 2022. Renault stopped disclosing common ZEV investment targets, so its investment amount reflected its reported ZEV investment from 2016 to 2023. This resulted in ZEV investments between $410 and $430 per vehicle. Nissan's per-vehicle investment dropped because its announcement included its e-Power hybrid models in its investment strategy; we thus assumed an equal split in investment between ZEVs and conventional hybrids.

Automakers also began to invest in raw materials to secure the supply for EV battery production over the long term. Table B6 in Appendix B provides further details on the total aggregated investment amount. VW led in terms of total investments in minerals with two main joint ventures with Umicore in Europe and Huayou Cobalt and Tsingshan Group to secure nickel and cobalt in China. Ford followed with its investment in nickel, also with Huayou Cobalt in Indonesia. Other manufacturers also secured raw materials, notably lithium (including GM with Lithium Americas, Mercedes-Benz with Rock Tech Lithium, and BMW with European and Australian companies). According to the Government of Indonesia, Tesla plans to invest in nickel supply in Indonesia, though Tesla has not publicly confirmed the report. Tesla's capital expenditures already include all investments, including those targeted at minerals and charging infrastructure. Data on raw material investments were limited at the time of our analysis; no information was found on investments in the mineral supply chain by Japan-based manufacturers.

Some manufacturers announced investments in charging infrastructure as part of their ZEV investment commitments; however, as in our previous analysis, investment in this area remains low. By the end of 2023, the proportion of charging infrastructure investment among legacy automakers was between 0.5% and 2.9% of the total per-vehicle investment amount. This is much lower when compared to an all-electric automaker such as Tesla, whose investment in its supercharging network accounted for approximately 16% of its total per-vehicle investment. A major development in charging was announced last year when a group of seven manufacturers (BMW, GM, Honda, Hyundai-Kia, Mercedes-Benz, Stellantis, and VW) revealed an investment of approximately $1 billion in a joint venture to build EV chargers across the United States. This joint venture follows a similar business model to that of IONITY in Europe, which aims to accelerate the provision of fast charging infrastructure across Europe (Colias et al., 2023).

5.3 Executive compensation alignment

The executive compensation alignment metric is an indicator of the degree of alignment between CEO compensation and EVs. Executive compensation is typically structured to encourage CEOs to focus on delivering certain outcomes. Historically, most CEO compensation packages have been linked to short-term financial performance indicators like earnings before interest and taxes and free cash flow; however, investment in the zero-emission transition is a long-term investment that is not reflected in short-term financial performance to the same extent as profits generated by traditional ICEVs. Therefore, linking CEO compensation directly to EV development shows the increasing importance of ZEV transition in a company's overall business strategy and indicates higher likelihood that CEOs will focus on ZEVs.

METHODOLOGY

The evaluation for this metric is based on the compensation structure, performance and financial criteria, and weightings of components used by each manufacturer to determine the compensation of chief executives. The information was extracted from proxy statements, public filings, and annual reports of each manufacturer. A proxy statement contains the information that the U.S. Securities and Exchange Commission and similar institutions in other regions require companies to provide to shareholders so they can make informed decisions about matters discussed during annual general or special shareholder meetings. Proxy statements are issued by companies annually and include key topics to be voted on by shareholders as well as executive and board compensation and other information. The proxy statements and other relevant reports reviewed for this rating were statements that reflected the compensation structure for fiscal year 2023 or the latest previous year available for each automaker. We collaborated with Valens Research, an investment research firm specializing in accounting analytics and corporate valuation and performance, to collect the information related to executive compensation specifically for this metric.

The compensation of the chief executive of a company is usually made up of two types of incentives in addition to any fixed compensation: short-term incentives and long-term incentives. Generally, short-term incentives reward performance that are achieved within 1 year. Long-term incentives are usually provided to induce an executive to achieve results 3 years or more in the future. The proportion of incentives varies by manufacturer and there are cases where the entire compensation package is determined solely by short-term incentives or long-term incentives. We determine the weight of different types of incentives in the total compensation based on the stated distribution of each incentive. In cases where such information is not clearly indicated, we use the proportion of the actual compensation paid in the previous year. Upon the approval of the board of the compensation committee, companies usually set financial and non-financial indicators and performance criteria under each type of incentive to determine the compensation package and incentive plans.

For this metric, we evaluate the percentage of compensation that directly depends on ZEV or EV development. Besides the parameters that are clearly linked to EVs, we also give partial credit for parameters associated with CO_2 emissions. The adjustment factor for CO_2 emissions is 50% because there are ways other than electrification to achieve CO_2 emission targets. In a change from the previous report, we no longer take account of elements linked to ESG parameters in this analysis unless EVs or CO_2 emissions are directly stated as part of ESG. We made this refinement to the methodology because we believe that ESG is too broad to link to EVs and plays a minimal role in incentivizing EV development as part of the company's business strategy. Further, we do not adjust for PHEV sales because the split between ZEVs and PHEVs in the compensation incentive is not clear for most manufacturers. This approach keeps our analysis at the same granularity across automakers.

We first identified the types of incentives that were linked to EVs and CO_2 emissions elements for the compensation of the CEO or equivalent officer at each automaker. Then we calculated the percentage of the executive compensation that was determined by the element. Tesla and BYD, which exclusively produce and sell EVs, received a default score of 100% because all their growth and profits derive from EVs. We identified compensation incentives that are linked to EVs among legacy manufacturers and allocated the scores based on the weight of incentives linked to the two elements. The top-performing legacy automakers received the maximum score along with Tesla and BYD.

We converted the final value of the adjusted compensation percentage to a 100-point scale using Equation (1). We identified the historical best and worst performers from reporting years 2022 and 2023 and assigned a score of 100 to the former and zero to the latter.

RESULTS

Besides BYD and Tesla, seven manufacturers incorporated direct EV measures into their executive compensation structure. Table 4 presents a list of manufacturers that link compensation incentives to EV development and CO_2 emissions, the weight in the compensation, and the final score. Other manufacturers not in the table do not disclose their executive compensation structure for any of the selected elements.

Table 4

Metric scores for executive compensation alignment with EV development.

OEM	Element in executive compensation		Adjusted percentage of total compensation 2023	Adjusted percentage of total compensation 2022	2023 score	2022 score	Score changes
	Linkage	Description[a]					
BYD	EV-only manufacturer				100	100	0
Tesla	EV-only manufacturer				100	100	
Stellantis	EV	50% of transformation incentives (16%)	27%	19%	100	100	0
		30% of long-term incentives (52%)					
		15% of short-term incentives (19%)					
BMW	EV	50% of share-based remuneration's strategic focus target (17.5%)	16%	15%	60	80	-20
		17% of short annual bonus' performance target (17%)					
	CO_2 emissions	50% of share-based remuneration's strategic focus target (17.5%)					
GM	EV	15% of long-term incentives (76%)	15%	11%	55	57	-2
		20% of short-term incentives (16%)					
Renault	EV	25% of long-term incentives (24%)	6%	7%	24	37	-13
	CO_2 emissions	20% of co-investment plan (4%)					
Mercedes-Benz	EV	7% of long-term incentives (39%)	3%	2%	15	12	3
	CO_2 emissions	8% of annual bonus (30%)					
Ford	EV	20% of short-term incentives (15%)	3%	N/A	11	0	11
VW	CO_2 emissions	17% of annual bonus (26%)	2%	5%	8	26	-18
Nissan	EV	5% of performance-based cash incentives (28%)	1%	N/A	5	7	-2
Volvo Cars (Geely)	CO_2 emissions	30% of long-term incentives (22%)	1%	N/A	4	0	4
Jaguar Land Rover (Tata Motors)	CO_2 emissions	17% of performance-based strategic bonus (33%)	1%	N/A	4	0	4

[a] Percentages in parentheses reflect the size of that compensation element in the total compensation portfolio.

Ford and Mercedes-Benz aligned their executive compensation to EV development for the first time in 2023. Stellantis, BMW, and GM increased the weighting of EV development in the determination of their compensation packages. Volvo Cars (owned by Geely) and JLR (owned by Tata Motors) newly linked their compensation to CO_2 emissions reduction targets.

More specifically, Ford received scores for newly linking 20% of its short-term annual performance bonus criteria to the EV global retail volume. Mercedes-Benz selected EV sales share as one of the targets to determine its long-term compensation, at a weight of 20% of its long-term incentive. Volvo Cars (Geely) incorporated CO_2 emissions to determine its long-term performance share plan and JLR (Tata Motors) linked 2030 CO_2 reduction targets to its strategic bonus plan.

Stellantis remained in a leading position with the highest percentage of total executive compensation linked to EV development, apart from Tesla and BYD. The automaker added an EV component to the short-term incentive, removed the CO_2 emission component in the long-term incentive, and increased the weighting of EV sales from 10% to 30% to determine its long-term incentive. Stellantis also maintained its one-time CEO transformation incentive that is determined by a set of key milestones related to EV and other technology development, such as software engineering advancement, by the end of 2025.

BMW, meanwhile, incorporated EVs in both short-term and long-term incentives. In 2023, it newly linked ZEV sales to the performance component of its short-term annual bonus in addition to linking the strategic focus targets of the long-term share-based compensation incentive to ZEV and CO_2 emissions reduction. GM, for its part, incorporated a new EV criterion linked to its short-term compensation incentive; four of the five strategic goals that comprise 25% of its short-term incentive are linked to EVs. This is in addition to the 15% of the long-term incentives that is determined based on EV criteria, namely EV volume, launch timing, and quality.

Consistent with 2022, Renault used both EVs and CO_2 emissions reduction to determine its long-term incentives; approximately 25% of the long-term incentives for its top executive were linked to electrified passenger car sales[10] and 20% of the co-investment plan is linked to CO_2 emissions reduction in Europe, its largest market. Similarly, approximately 5% of Nissan's performance-based cash incentive was determined by carbon neutrality efforts, which specifically mentioned EV development. However, this element only affects 1.4% of total compensation.

Note that the share of compensation linked to elements like long-term and short-term incentives can vary from year to year, which affects the resulting EV-related percentages. In addition, because Stellantis greatly increased the linkage to EV development in its compensation package, the best performer benchmark was higher compared with last year. Thus, the metric scores of some manufacturers declined from the 2022 report even though their actual compensation structure may not have changed or may even reflect increased linkage to EVs. In addition, some scores declined as we removed credit for ESG linkages in executive compensation. The general trend of these manufacturers shows that the success in the electrification transition is increasingly seen as critical to the future financial viability of the automotive industry.

10 Although "electrified passenger cars" are not defined in the document, given that Renault has set targets to sell only ZEVs in Europe, we assume that "electrified" vehicle here does not include non-plug-in hybrids.

6

FINAL RATING RESULTS AND DISCUSSION

6 FINAL RATING RESULTS AND DISCUSSION

This report assesses the world's top 21 automakers in the context of the global vehicle market's transition to ZEVs. The companies that successfully navigate the transition by preparing to maintain or grow their ZEV market share are expected to be best positioned for success in a decarbonized future.

Table 5 shows the final ratings of the 21 manufacturers and their rating on each of the 10 metrics considered. The final rating score and the total score for each pillar—market dominance, technology performance, and strategic vision—are shown in colors. Consistent with 2022, we categorized automakers based on their scores into three groups: "Leaders" within the top third of the ratings (66.7–100, in green), "Transitioners" (33.4 to 66.6, in yellow), and "Laggards" (0–33.3, in red). The final rating is calculated by averaging the scores of the three pillars.

Table 5

Overall scores, The Global Automaker Rating 2023.

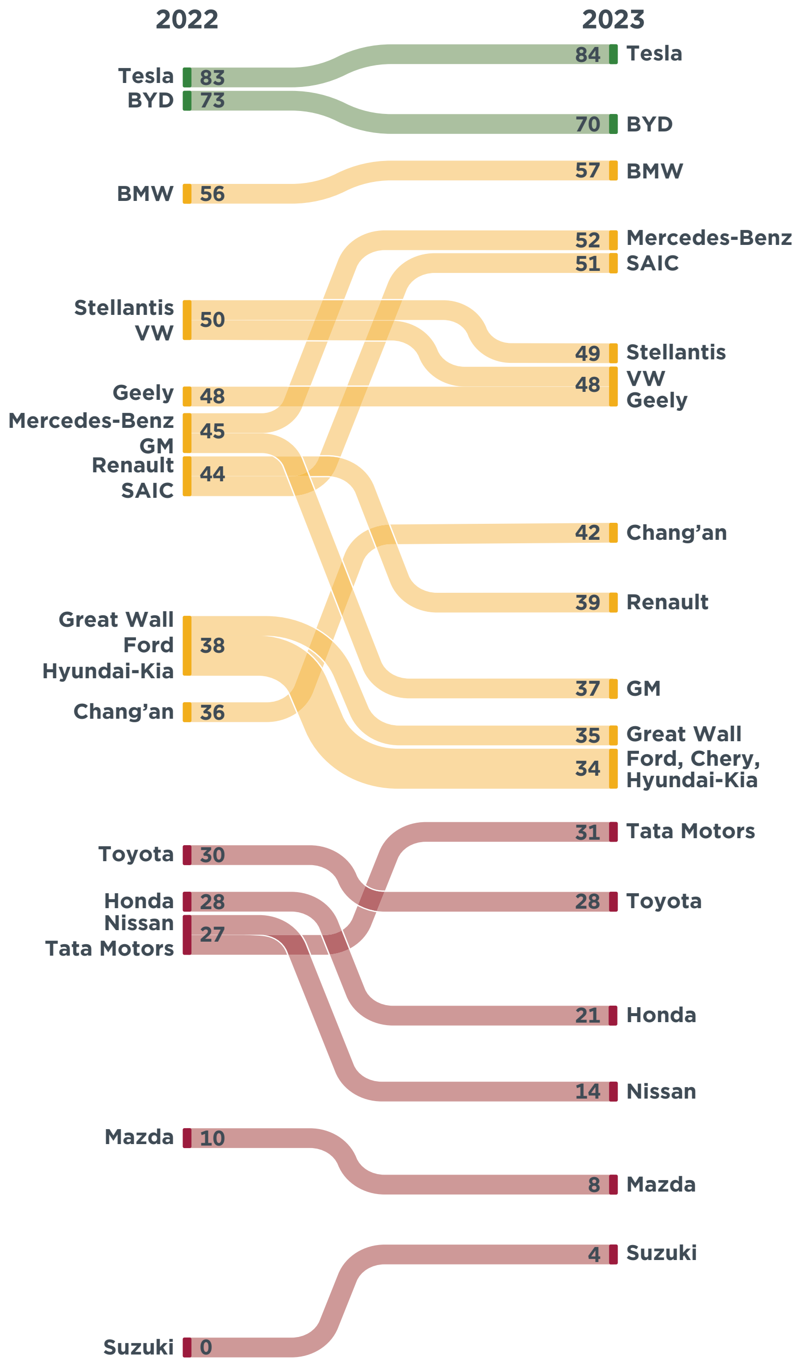
	2023 rating		MARKET DOMINANCE			TECHNOLOGY PERFORMANCE						STRATEGIC VISION			
			ZEVe sales share	ZEV class coverage	Pillar score	Energy consumption	Charging speed	Driving range	Renewable energy	Battery recycle/ repurpose	Pillar score	ZEV target	ZEV investment	Executive compensation	Pillar score
Tesla	84	LEADERS	100	46	73	94	100	100	0	100	79	100	100	100	100
BYD	70	LEADERS	76	77	77	69	25	64	0	100	52	76	68	100	81
BMW	57	TRANSITIONERS	17	55	36	73	54	90	100	93	82	84	17	60	54
Mercedes-Benz	52	TRANSITIONERS	15	50	33	50	43	82	100	93	74	90	42	15	49
SAIC	51	TRANSITIONERS	40	100	70	56	13	26	0	83	36	73	65	0	46
Stellantis	49	TRANSITIONERS	9	68	39	31	31	35	0	99	39	100	7	100	69
VW	48	TRANSITIONERS	11	59	35	61	50	87	73	97	74	79	22	8	36
Geely	48	TRANSITIONERS	29	78	54	37	35	51	7	98	46	87	45	4	45
Chang'an	42	TRANSITIONERS	21	93	57	39	5	21	0	100	33	73	36	0	36
Renault	39	TRANSITIONERS	10	74	42	41	15	27	0	95	36	84	11	24	40
GM	37	TRANSITIONERS	4	19	12	59	29	75	0	74	47	87	10	55	51
Great Wall	35	TRANSITIONERS	17	46	32	46	18	53	0	100	43	89	3	0	31
Ford	34	TRANSITIONERS	4	30	17	23	48	86	14	92	53	79	11	11	34
Chery	34	TRANSITIONERS	17	78	48	46	4	4	0	100	31	58	17	0	25
Hyundai-Kia	34	TRANSITIONERS	7	30	19	26	79	71	11	100	57	54	21	0	25
Tata Motors	31	LAGGARDS	8	23	16	100	5	42	7	81	47	71	20	4	32
Toyota	28	LAGGARDS	2	28	15	71	32	82	6	59	50	48	9	0	19
Honda	21	LAGGARDS	1	6	4	35	26	54	0	42	31	67	19	0	29
Nissan	14	LAGGARDS	5	28	17	18	22	30	0	33	21	0	9	5	5
Mazda	8	LAGGARDS	2	3	3	0	19	2	0	0	4	38	15	0	18
Suzuki	4	LAGGARDS	0	0	0	N/A	N/A	N/A	0	0	0	32	4	0	12

Tesla and BYD continued to lead the ZEV transition in 2023. Both companies also grew their EV sales, with BYD sales increasing by nearly 100% and Tesla sales increasing by about 40% compared with 2022. Tesla has only produced ZEVs since its inception but still has an opportunity to diversify its ZEV products by introducing models in more vehicle classes. BYD reached 100% EV sales share in 2023, but 48% of its new sales were PHEVs. To maintain its leadership in the ZEV transition, BYD will eventually need to phase out its PHEVs and improve its ZEV performance and class coverage.

Figure 9 shows the 2023 ratings of the 21 manufacturers compared with their 2022 ratings.

Figure 9

2022 versus 2023 Global Automaker Rating.



*The figure is not drawn to scale.

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Mercedes-Benz, **SAIC, and Chang'an showed the greatest improvement in their final scores compared with 2022.** Mercedes-Benz made the greatest improvement in efforts to decarbonize its supply chain. SAIC had the fastest growth in ZEV-equivalent sales share, of 9 percentage points, along with significant improvement in ZEV performance. Chang'an, meanwhile, increased its ZEV-equivalent sales share by 5 percentage points and was the most improved automaker in the deployment of battery recycling and repurposing.

Automakers based in Japan and India are still at the bottom of our rating, but Tata Motors and Suzuki have shown noticeable progress. Tata Motors increased its ZEV-equivalent sales share to 8% in 2023 and strengthened its ZEV target ambition, ZEV investment, and the performance of its BEV products. With continued improvement, the automaker could move into the Transitioner group in future ratings. Suzuki remained at the bottom of our rating but set 2030 ZEV targets for the first time, of 80% in Europe, 20% in Japan, and 15% in India. The automaker also increased its announced ZEV investment to $14 billion, around $160 per vehicle. Meanwhile, Toyota, Honda, Nissan, and Mazda made limited improvements in ZEV-equivalent sales share, with increases of around one percentage point each, achieving sales shares of only 1%–5% in 2023. These automakers are far behind industry leaders and need to catch up on diversifying their ZEV offerings and increasing ZEV investment.

Table 6 shows rating changes by automaker and by metric in this analysis from 2022 to 2023.

Table 6

Comparison of overall and metric scores, 2023 versus 2022.

			MARKET DOMINANCE				TECHNOLOGY PERFORMANCE										STRATEGIC VISION					
OEM	2023 overall		ZEVe sales share		ZEV class coverage		Energy consumption		Charging speed		Driving range		Renewable energy		Battery recycle/ repurpose		ZEV target		ZEV investment		Executive compensation	
Tesla	84	▲ 1	100	0	46	▲ 8	94	▼ 6	100	0	100	0	0	0	100	0	100	0	100	0	100	0
BYD	70	▼ 3	76	▲ 7	77	▼ 11	69	▼ 5	25	▼ 13	64	▼ 9	0	0	100	0	76	▲ 6	68	▼ 11	100	0
BMW	57	▲ 1	17	▲ 5	55	▲ 5	73	▲ 1	54	▲ 2	90	▲ 14	100	0	93	▲ 1	84	▲ 12	17	▼ 3	60	▼ 20
Mercedes-Benz	52	▲ 7	15	▲ 5	50	▼ 13	50	▼ 5	43	▲ 2	82	▲ 9	100	▲ 50	93	▲ 50	90	▼ 6	42	▲ 8	15	▲ 3
SAIC	51	▲ 7	40	▲ 9	100	0	56	▲ 7	13	▲ 13	26	▲ 26	0	0	83	▼ 7	73	▲ 36	65	▼ 16	0	0
Stellantis	49	▼ 1	9	▲ 1	68	▼ 20	31	▲ 3	31	▼ 5	35	▲ 7	0	0	99	▲ 1	100	▲ 19	7	▼ 2	100	0
VW	48	▼ 2	11	▲ 1	59	▼ 29	61	▲ 1	50	▼ 1	87	▲ 5	73	▼ 2	97	▲ 48	79	▲ 18	22	▼ 1	8	▼ 18
Geely	48	0	29	▲ 6	78	▼ 10	37	▼ 8	35	▲ 3	51	▼ 17	7	▼ 2	98	▼ 2	87	▲ 16	45	▼ 1	4	▲ 4
Chang'an	42	▲ 6	21	▲ 5	93	▲ 5	39	▼ 6	5	▲ 1	21	▲ 2	0	0	100	▲ 100	73	▲ 5	36	▼ 20	0	0
Renault	39	▼ 5	10	▼ 1	74	▼ 1	41	▼ 8	15	▲ 2	27	▼ 5	0	0	95	▲ 5	84	▼ 16	11	▼ 11	24	▼ 13
GM	37	▼ 9	4	▲ 2	19	▼ 19	59	▲ 6	29	▼ 2	75	▼ 3	0	0	74	▼ 25	87	▼ 9	10	▼ 26	55	▼ 2
Great Wall	35	▼ 3	17	▲ 7	46	▼ 29	46	▼ 9	18	▲ 3	53	▲ 23	0	0	100	0	89	▼ 3	3	▼ 2	0	0
Ford	34	▼ 4	4	0	30	▲ 5	23	▼ 3	48	▼ 1	86	▼ 9	14	0	92	▲ 1	79	▼ 17	11	▼ 25	11	▲ 11
Chery	34		17		78		46		4		4		0		100		58		17		0	
Hyundai-Kia	34	▼ 4	7	▼ 1	30	▼ 33	26	▼ 6	79	▲ 4	71	▼ 2	11	0	100	0	54	▲ 15	21	▲ 1	0	0
Tata Motors	31	▲ 4	8	▲ 2	23	▼ 2	100	▲ 13	5	▲ 2	42	▲ 21	7	▲ 1	81	▼ 6	71	▲ 19	20	▲ 2	4	▲ 4
Toyota	28	▼ 2	2	▲ 1	28	▼ 35	71	▲ 28	32	▼ 3	82	▲ 12	6	0	59	0	48	▲ 9	9	▲ 2	0	0
Honda	21	▼ 7	1	▲ 1	6	▼ 32	35	▼ 16	26	0	54	▲ 2	0	0	42	▲ 10	67	▼ 6	19	▼ 5	0	0
Nissan	14	▼ 13	5	▲ 1	28	▼ 35	18	▼ 1	22	▲ 10	30	▲ 1	0	0	33	▲ 2	0	▼ 60	9	▼ 15	5	▼ 2
Mazda	8	▼ 2	2	▲ 1	3	▼ 10	0	0	19	0	2	▼ 1	0	0	0	0	38	▲ 8	15	▼ 10	0	0
Suzuki	4	▲ 4	0	0	0	0	N/A		N/A		N/A		0	0	0	0	32	▲ 32	4	▲ 4	0	0

Note: ▲ indicates score increase compared with 2022; ▼ indicates score decrease compared with 2022.

Across the 10 metrics analyzed in the report, there were six metrics on which most automakers improved in 2023 compared to 2022, one metric on which many scores worsened, and three metrics with little change.

SIX METRICS SHOWING IMPROVEMENT

ZEV-equivalent sales share. Fifteen automakers increased their ZEV-equivalent sales share in 2023. The overall ZEV-equivalent sales share of the top automakers in the six markets grew from 11% in 2022 to 15% in 2023. China-based automakers made up six of the top 10 performers, with ZEV-equivalent sales shares of 17%–76% in 2023. SAIC reached 40% sales share in 2023, following Tesla (100%) and BYD (76%). German-based manufacturers BMW and Mercedes-Benz grew their ZEV-equivalent sales by 5 percentage points each. Only Hyundai-Kia and Renault had a decline in ZEV-equivalent sales shares across the six major markets.

Energy consumption. Eleven automakers improved the average efficiency of BEVs sold, although only seven saw a score increase because of the higher benchmark set in 2023. Tata Motors bumped Tesla out of the top spot with a fleet-average energy consumption of 84 kW/km (114 kW/km after the weight adjustment). On average, the energy consumption of BEVs across top automakers declined from 140 Wh/km in 2022 to 135 Wh/km in 2023.

Driving range. Fourteen automakers increased the average driving range of their BEVs, an attribute important to consumers. Five (SAIC, Great Wall, BMW, Tata Motors, and Toyota) saw increases of more than 50 km. On average, the driving range of BEVs across top automakers increased from 395 km in 2022 to 419 km in 2023.

ZEV targets. Seven automakers showed a stronger commitment to the transition by increasing their ZEV targets in 2023. Five of them (Geely, SAIC, VW, Hyundai-Kia, and Tata Motors) increased targets for at least some of their brands by 5–20 percentage points. Suzuki announced its first-ever ZEV target, while BMW moved its 100% ZEV target for MINI from early 2030s to a clearly indicated year of 2031.

ZEV investment. Thirteen automakers increased their ZEV investment per vehicle. Tesla still leads in investment with $3,740 per vehicle. Other automakers that substantially bumped up ZEV investment are SAIC ($2,427), Geely ($1,677), Mercedes-Benz ($1,567), and Tata Motors ($756). Nevertheless, only some automakers saw a rating increase after benchmarking with Tesla's increased performance on this metric.

Executive compensation alignment. Automakers are making noticeable progress in incentivizing their executives to meet EV or CO_2 targets. Stellantis, BMW, and GM more heavily considered EVs in their executive compensation packages in 2023 compared to 2022. Ford and Mercedes-Benz linked executive compensation to EVs for the first time, while Volvo (owned by Geely) and JLR (owned by Tata Motors) added a CO_2 emission element to their compensation rubrics.

ONE METRIC SHOWING STRUGGLING PERFORMANCE

Class coverage. Nine automakers reduced their class coverage. Seven (Geely, Chang'an, VW, Hyundai-Kia, Nissan, Great Wall, and Honda) discontinued the production of BEVs or FCEVs in certain classes. In addition, two manufacturers (Great Wall and BYD) recorded dwindling sales of some of ZEV models, which may indicate a coming decision to discontinue them. For our 2023 rating, a methodological change to give automakers credit for offering a vehicle class only in the markets where more than 1,000 of those vehicles were sold led to a decline in scores for several automakers. Although we recalculated our benchmark to reflect this change, 14 automakers saw a score decrease from 2022 to 2023 for this metric.

THREE METRICS WITH LITTLE CHANGE

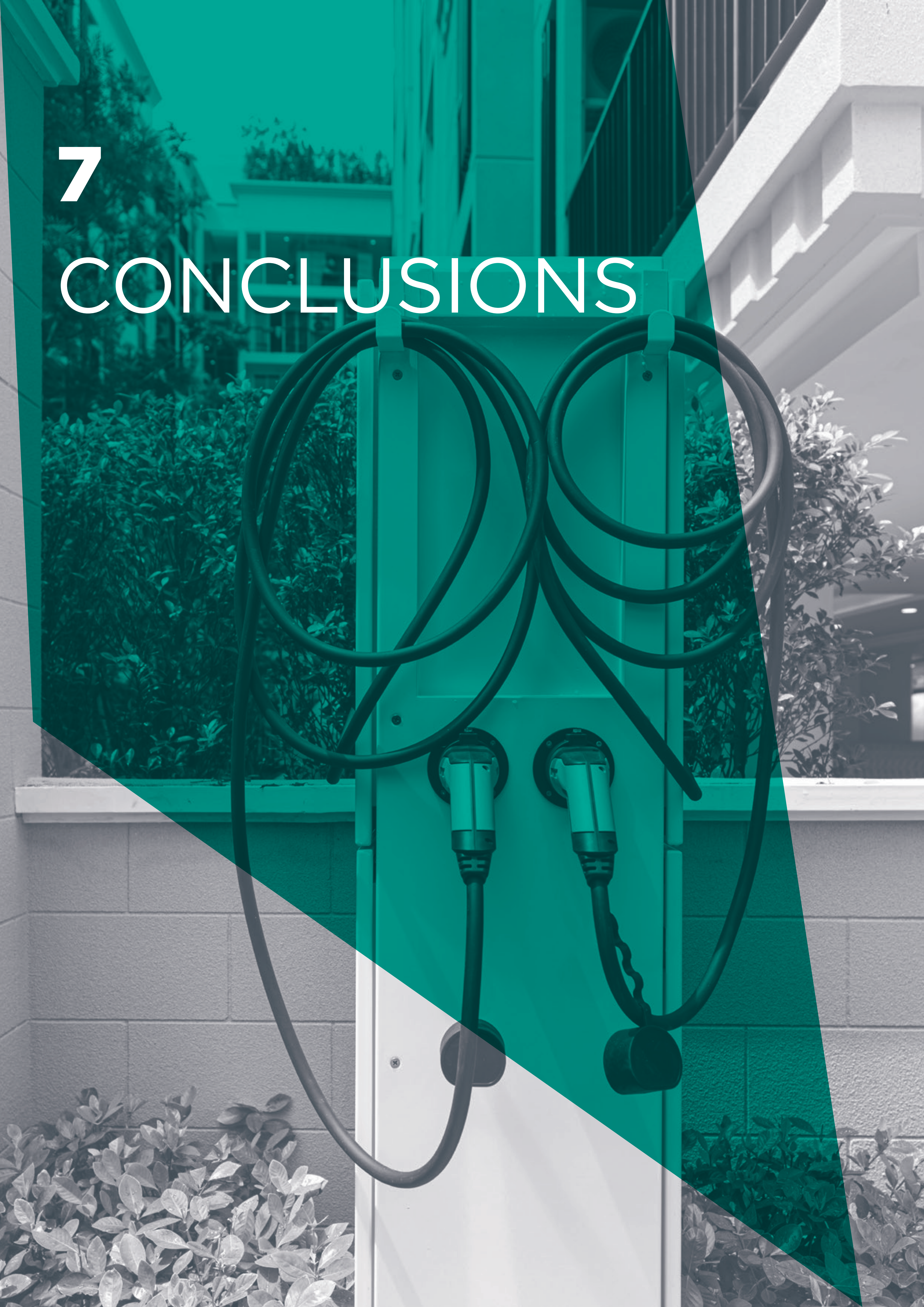
Renewable energy in manufacturing. Only Mercedes-Benz made big progress in using renewable electricity for vehicle and battery manufacturing, by requiring battery suppliers to be carbon neutral with an emphasis on using 100% renewable energy. Besides Mercedes-Benz, BMW and VW continued to lead on this metric. All other automakers need to take big actions to decarbonize their manufacturing processes.

Charging speed. Overall, most automakers had no notable change in average charging speeds across their BEV models.

Battery recycling and repurposing. Most manufacturers announced battery recycling and reusing projects in their major markets, with two automakers (VW and Mercedes-Benz) expanding their efforts in battery recycling and repurposing across multiple markets. Chang'an announced a battery recycling project in its home market, China. We noticed that some announced projects showed no evidence of implementation and, in the future, will consider differentiating between projects that are being implemented from those that are still in the planning stage.

7

CONCLUSIONS



7 CONCLUSIONS

Having rated the world's top 21 automakers in terms of their ZEV market dominance, technology performance, and strategic vision, we draw the following conclusions:

1. **Tesla and BYD continue to lead global manufacturers in the ZEV transition**. These two automakers are EV-only manufacturers, though almost half the vehicles BYD produced in 2023 were PHEVs. Nevertheless, BYD experienced a fast expansion from 2022 to 2023, doubling its sales in the six key markets we examined. **SAIC, Mercedes-Benz, and Chang'an** improved most in their final scores compared with 2022.

2. **Automakers based in Japan and India are still at the bottom of our rating, but Tata Motors and Suzuki have shown noticeable progress. Tata Motors** increased its ZEV target ambition and ZEV investment per vehicle, along with substantial improvement in the energy consumption and driving range of ZEVs sold to the major markets. With such momentum, Tata Motors may be able to jump ahead of today's Transitioners in future ratings. **Suzuki,** which earned a 0 rating in 2022, inched up in score as it made progress on its ZEV strategy. **Toyota**, **Honda**, **Nissan**, and **Mazda** remained at 1%–5% ZEV-equivalent sales shares, and all need to catch up on diversifying their ZEV offerings and increasing ZEV investment.

3. **Most automakers are growing ZEV sales shares, improving ZEV technology, and increasingly planning for the ZEV future.** Fifteen automakers increased their ZEV-equivalent sales share. SAIC grew most (by nine percentage points) to reach a 40% sales share, third to Tesla (100%) and BYD (76%). Eleven automakers improved the average efficiency of BEVs sold. The improvement in energy efficiency also partially contributed to the trend of increased average driving range of BEVs sold by most automakers. Both technology features are important to consumers. Such a positive trend will likely continue as automakers boost their ZEV targets and ZEV investment and incentivize their executives by increasingly linking their compensation packages to EVs.

4. **Automakers need to pick up the pace on ZEV model offerings.** Nine manufacturers discontinued the production of certain ZEV models or seem likely to discontinue models with dwindling sales.

This report on automakers' 2023 ZEV performance is our first chance to track changes in manufacturers' positions in the global ZEV transition. As automakers innovate and improve their ZEV offerings, reduce their upstream emissions, and invest in a ZEV future, we will see more changes in the benchmarks among manufacturers.

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APPENDIX A. DATA PROCESSING AND SOURCES

For manufacturer-specific actions, information about the use of renewable energy in manufacturing, battery recycling and repurposing, ZEV targets, ZEV investments, procurement agreements, and direct investments in battery raw materials and charging infrastructure were primarily sourced from the manufacturers' latest annual sustainability reports. Table A1 includes the complete list of annual sustainability reports and supplementary sources reviewed for this analysis.

To assess the performance of the top 21 automakers in the ZEV transition, we created a database that includes sales data for all LDVs sold in 2023 by powertrain in six global markets: the United States, Korea, Japan, Europe, India, and China. The database also includes vehicle specifications of the EV models offered by the top 21 automakers in 2023.

To maximize coverage and accuracy, we compiled vehicle data from multiple sources. The data regarding global vehicle sales and vehicle power train type were derived from four sources for new vehicles sold in 2023: United States, Korea, and Japan data from MarkLines (MarkLines, 2023); Europe data—including vehicle sales in the European Union, European Free Trade Association (EFTA) member states, and the United Kingdom—from Dataforce (Dataforce, 2023); India data from Segment Y (Segment Y, 2023); and China data provided by WAYS (WAYS, 2023). Data on ZEV specifications (length, gross vehicle weight rating, curb weight, gross battery capacity, energy consumption, driving range, and charging time) of each model were collected from major EV information hubs including ev-database.org, evspecifications.com, and EV-Volumes (EV-Volumes, 2023) for models sold in the United States, Korea, Japan, Europe, and India; yiche.com and autohome.com for models sold in China; and from brochures on manufacturers' official websites.

As this study centers on LDVs, we included LCVs. To eliminate medium- and heavy-duty commercial vehicles from our database, we applied an upper threshold of 3,500 kg for non-U.S. LCVs and 3,856 kg for U.S. LCVs, because the definition of LCVs in the United States is a bit broader than it is in the other markets.

For joint ventures in China where manufacturers not headquartered in China collaborate with a China-headquartered counterpart under a technology-sharing agreement, we distinguished vehicles that were manufactured as non-domestic or domestic brands and counted the sales toward the corresponding controlling corporate entity. This was done across various data sources. For instance, although Buicks sold in China are produced by SAIC, we attributed their sales to GM because Buick is a GM brand and its models are mainly designed and determined by GM. Table A2 lists the top 21 manufacturers and their major brands.

To match the vehicle specification database with the EV sales database, we used model-level matching instead of variant-level matching; this is because sales information was not available at the variant level across all six regions. In cases where a model had multiple variants with different specifications, including things such as battery size and range, we calculated the average of all variants to obtain the representative model specification.

New for this edition of the report, for vehicle specification related metrics (class coverage, energy consumption, charging speed, and driving range), we applied a threshold that required sales of the model within the six major markets to exceed 100 units[11] for the initial screening process. Setting such a threshold helped to exclude models that are still produced at sub-commercial scale. The total sales of those models accounted for 0% to 0.2% of the ZEV sales for each automaker, minimally impacting the sales-weight average calculation of BEV specification-related metrics.

Table A1

Manufacturer reports and public resources used in the rating.

OEM	Sustainability reports	Other sources
BMW	2023 BMW Group Report	
BYD	2023 BYD CSR Report	
Chang'an	2023 Semi-Annual Report	
Chery	2023 CSR Report	
Ford	2024 Integrated Sustainability and Financial Report	2023 Ford Motor Company Proxy Statement
Geely	2023 Geely Group ESG Report	
	2023 Volvo Car Annual and Sustainability Report	
GM	2023 Sustainability Report	2023 GM Proxy Statement
		2023 Sustainability Advocacy Report
Great Wall	2023 Corporate, Social, and Responsibility Report	
Honda	2023 ESG Data Book	2023 Honda Integrated report
		FY2023 Honda 20-F Form
Hyundai-Kia	2023 Sustainability Report (Hyundai)	
	2023 Sustainability Report (Kia)	
Mazda	2023 Sustainability Report	
Mercedes-Benz	2023 Sustainability Report	2023 Remuneration System Report
Nissan	2023 Sustainability Report	2023 Financial Information as of March 31, 2023
		Nissan's The Arc Business Plan Press Release
Renault	2022-2023 Integrated Report	2023 Board of Directors' Release
	2023 Governance Roadshow Presentation	
SAIC	2023 ESG Report	
Stellantis	2023 Corporate Social Responsibility Report	2023 Remuneration Report
Suzuki	2023 Sustainability Report	2023 Integrated Report
Tata Motors	2022-23 Integrated Annual Report	2023 Corporate Presentation
	2022/23 JLR Annual Report	
Tesla	2022 Impact Report	2023 10-K Form
Toyota	2023 Sustainability Data Book	2023 20-F Form
VW	2023 Sustainability Report	2023 Remuneration Report

11 For databases that cover the global market, we applied the 100-unit threshold. For databases that focus on a specific region (e.g., Chinese insurance data for China and Segment Y for India), we applied a regional threshold of 50 units to filter out models with small sales volumes. The rationale behind the regional filter is that regional databases contain model names that cannot be matched with models from global databases. This is particularly true for LCV models in China, which are identified by Catalogue number instead of a model name.

Table A2

List of top 21 manufacturers and major brands.

OEM	Major brand
BMW	BMW, MINI, Rolls-Royce
BYD	BYD, Denza, Fangchengbao, Yangwang
Chang'an	Chang'an, Avatr, Deepal, Kaicene, Kuayue, Oushang, Qiyuan
Chery	Chery, Exeed, iCar, Jetour, Kaiyi/Cowin,Karry, Luxeed, Qijie, Qoros, ZX
Ford	Ford, Lincoln
Geely	Geely, Caocao, Geometry, LEVC, Livan, Lotus, LYNK & CO, Maple, Ouling, Polestar, Radar, Volvo Cars, Yuancheng, ZD, Zeekr
GM	GM, BrightDrop, Buick, Cadillac, Chevrolet, GMC, Hummer
Great Wall	Great Wall, Haval, Ora, Tank, Wey
Honda	Honda, Acura
Hyundai-Kia	Genesis, Hyundai, Kia
Mazda	Mazda
Mercedes-Benz	Mercedes-Benz, Mercedes-Maybach, Smart
Nissan	Nissan, Datsun, Infiniti
Renault	Renault, Alpine, Dacia, JMEV
SAIC	Baojun, Clever, IM Motors, Maxus, MG, R Auto, Roewe, Wuling (SAIC), Yuejin
Stellantis	Abarth, Alfa Romeo, Chrysler, Citroen, Dodge, DS, Fiat, Fukang, Jeep, Lancia, Maserati, Opel/Vauxhall, Peugeot, Ram
Suzuki	Suzuki, Maruti
Tata Motors	Tata, Jaguar, Land Rover
Tesla	Tesla
Toyota	Toyota, Daihatsu, Lexus
VW	Audi, Bentley, Bugatti, Cupra, Jetta, Lamborghini, MAN, Porsche, SEAT, Skoda, Volkswagen

APPENDIX B. SUPPLEMENTARY DATA FOR METRIC SCORING

B.1. ZEV-EQUIVALENT SALES SHARE

Table B1 compares the 2022 and 2023 scores for the ZEV-equivalent sales share metric for each automaker. It also details the ZEV-equivalent sales share of each manufacturer across the six major markets and shows their total ZEV and PHEV sales shares globally. The final score of the ZEV-equivalent sale share metric is calculated from the ZEV-equivalent share for each automaker, and the final score is shown in the rightmost column.

Table B1

2022 vs. 2023 score comparison and ZEV-equivalent sales share by manufacturer and region.

OEM	ZEV-equivalent share[a]						Global			2023 score	2022		Score changes
	China	U.S.	Europe	Japan	India	Korea	ZEV	PHEV	ZEVe		ZEVe	Score	
Tesla	100%	100%	100%				100%	0%	100%	100	100%	100	0
BYD	76%			100%*	100%*		52%	48%	76%	76	69%	69	7
SAIC	40%		48%	—	23%		40%	2%	40%	40	31%	31	9
Geely	27%	26%	42%	17%*	35%*	16%*	24%	12%	29%	29	23%	23	6
Chang'an	21%						14%	11%	21%	21	16%	16	5
Chery	17%						17%	1%	17%	17	N/A	N/A	N/A
BMW	13%	14%	24%	9%	12%	12%	15%	7%	17%	17	12%	12	5
Great Wall	17%		51%*				10%	13%	17%	17	10%	10	7
Mercedes-Benz	10%	12%	20%	10%*	4%*	13%	13%	7%	15%	15	10%	10	5
VW	6%	12%	14%	14%	1%*	10%*	10%	3%	11%	11	10%	10	1
Renault	100%*		10%	—	—	—	10%	1%	10%	10	11%	11	-1
Stellantis	5%*	3.3%*	12%	6%*	15%*	10%*	7%	7%	9%	9	8%	8	1
Tata Motors	0.5%	0.8%*	10%*	0.5%	10%	—	7%	4%	8%	8	6%	6	2
Hyundai-Kia	0.3%*	6%	16%	99%*	0.3%*	6%	7%	2%	7%	7	8%	8	-1
Nissan	0.4%*	2%	10%	11%	—		5%	0%	5%	5	4%	4	1
GM	7%	3%	—	—		5%*	4%	0%	4%	4	2%	2	2
Ford	1%*	4%	5%	—		0.1%	3%	2%	4%	4	4%	4	0
Mazda	0.2%*	0.7%*	7%	0.4%*			1%	4%	2%	2	1%	1	1
Toyota	2%	1%	4%	0.6%*	—	3.5%*	1%	1%	2%	2	1%	1	1
Honda	2%	—	4%*	0.05%*	—	—	0.4%	1%	1%	1	0%	0	1
Suzuki			—	—	—		0%	0.1%	0.03%	0	0%	0	0

[a] Asterisks signify that the automaker's total ZEV-equivalent sales in the respective region were fewer than 5,000. Cells shaded in gray indicate that no LDVs were sold in that market and cells filled with a dash denote that no EV sales occurred in that market.

B.2. ENERGY CONSUMPTION

Table B2 compares the 2022 and 2023 scores for the energy consumption metric for each automaker. It also shows the sales-weighted average adjusted energy consumption before and after the adjustment by curb weight in 2022 and 2023. Automakers are ordered from top to bottom starting with the lowest sales-weighted average energy consumption for their 2023 BEV sales.

Table B2

2022 vs. 2023 score comparison and sales-weighted fleet-average energy consumption of BEVs by manufacturer.

OEM	Average WLTP energy consumption (Wh/km)		2023 score	Average WLTP energy consumption (Wh/km)			2022 score	Score changes
	2023 original	2023 adjusted		2022 original	2022 adjusted (22 parameters)	2022 adjusted (23 parameters)		
Tata Motors	84	114	100	116	122	126	100	0
Tesla	128	117	94	138	123	128	97	-3
BMW	148	129	73	151	132	136	77	-4
Toyota	139	130	71	159	146	151	43	28
BYD	124	131	69	133	130	135	80	-11
VW	152	136	61	159	139	143	61	0
GM	139	136	59	145	145	148	50	9
SAIC	110	138	56	103	137	142	63	-7
Mercedes-Benz	161	141	50	161	140	144	58	-8
Chery	106	144	46					
Great Wall	136	144	46	124	136	140	67	-21
Renault	124	146	41	123	140	144	57	-16
Chang'an	120	148	39	116	140	145	56	-17
Geely	149	149	37	157	144	149	47	-10
Honda	146	150	35	139	139	144	59	-24
Stellantis	141	152	31	142	150	154	34	-3
Hyundai-Kia	163	155	26	161	150	155	33	-7
Ford	186	156	23	177	154	158	24	-1
Nissan	151	159	18	147	154	159	23	-5
Mazda	169	169	0	168	164	169	0	0
Suzuki								

B.3. CHARGING SPEED

Table B3 compares 2022 and 2023 scores for the charging speed metric for each automaker. It also shows the sales-weighted average charging speed for each automaker for BEVs that do not support fast charging and BEVs that support fast charging, and the sales share of each BEV group for each automaker. The table also summarizes the sales-weighted average charging speed considering the maximum average charging speed from BEV models of each automaker and their final scores for this metric.

Table B3

2022 vs. 2023 score comparison for average charging speed and breakdown by normal-charging capable only and fast-charging capable BEVs, by manufacturer.

	Charger type		Market share (%)						
OEM	Normal (kW)	Fast (kW)	Normal (kW)	Fast (kW)	2023 max avg (kW)	2023 score	2022 max avg (kW)	2022 score	Score changes
Tesla		172		100%	172	100	172	100	0
Hyundai-Kia		139		100%	139	79	134	75	4
BMW		102		100%	102	54	98	52	2
VW		95		100%	95	50	96	51	-1
Ford		91		100%	91	48	93	49	-1
Mercedes-Benz	5	89	6%	94%	84	43	81	41	2
Geely		72		100%	72	35	67	32	3
Toyota	2	68	0%	100%	68	32	72	35	-3
Stellantis	2	69	5%	95%	66	31	73	36	-5
GM		63		100%	63	29	65	31	-2
Honda		58		100%	58	26	58	26	0
BYD	5	57	0%	100%	57	25	76	38	-13
Nissan		51		100%	51	22	36	12	10
Mazda		47		100%	47	19	47	19	0
Great Wall		46		100%	46	18	41	15	3
Renault	2	42	0%	100%	42	15	38	13	2
SAIC	8	58	41%	59%	38	13	18	0	13
Chang'an	4	26	0%	100%	26	5	24	4	1
Tata Motors		26		100%	26	5	22	3	2
Chery	11	24	2%	98%	24	4			
Suzuki									

B.4. DRIVING RANGE

Table B4

2022 vs. 2023 score comparison for driving range.

OEM	2023 driving range (km)	2023 score	2022 driving range (km)	2022 score	Score changes
Tesla	527	100	503	100	0
BMW	495	90	429	76	14
VW	483	87	447	82	5
Ford	481	86	488	95	-9
Mercedes-Benz	469	82	420	73	9
Toyota	467	82	412	70	12
GM	445	75	434	78	-3
Hyundai-Kia	432	71	420	73	-2
BYD	407	64	420	73	-9
Honda	376	54	355	52	2
Great Wall	373	53	289	30	23
Geely	367	51	405	68	-17
Tata Motors	334	42	262	21	21
Stellantis	313	35	283	28	7
Nissan	296	30	285	29	1
Renault	284	27	295	32	-5
SAIC	281	26	196	0	26
Chang'an	267	21	254	19	2
Chery	209	4			
Mazda	203	2	205	3	-1
Suzuki					

B.5. ZEV TARGET

Table B5 shows the announced targets, year, scope of target, and score changes, and presents the comparison between 2023 and 2022 scores adjusted to the new methodology.

Table B5

2022 vs 2023 score comparison and announced EV sales targets by manufacturer

OEM	Brand	Electric vehicle (EV) sales target					2023 score	2022 score adjusted	2022 score	Score changes
		Region	EV sales	Vehicle category	Year	Type				
Tesla	All	Global	100%	PC+LCV	N/A	ZEV	100	100	100	0
Stellantis	All	Europe	100%	PC	2030	ZEV	100	92	81	19
		U.S.	50%	PC+LCV	2030	ZEV				
Mercedes-Benz	All	Leading markets	50%	PC+LCV	2030	ZEV, PHEV	90	89	96	-6
		Leading markets	100%	PC+LCV	2035	ZEV				
Great Wall	All	Global	80%	PC+LCV	2025	ZEV, PHEV	89	81	92	-3
Geely	Volvo Cars	Global	100%	PC+LCV	2030	ZEV	87	83	71	16
	Others	Global	50%	PC+LCV	2025	ZEV, PHEV				
GM	All	U.S.	50%	PC+LCV	2030	ZEV	87	78	96	-9
		Leading markets	100%	PC+LCV	2035	ZEV				
Renault	Renault	Europe	100%	PC	2030	ZEV	84	100	100	-16
	Dacia	Europe	100%	PC+LCV	2035	ZEV				
	Others	/	/	/	/	/				
BMW	BMW	Global	50%	PC+LCV	2030	ZEV	84	81	72	12
	MINI	Global	100%	PC+LCV	2031	ZEV				
	Rolls-Royce	Global	100%	PC+LCV	2030	ZEV				
VW	VW	Europe	80%	PC	2030	ZEV	79	68	62[a]	17
	VW	U.S.	55%	PC+LCV	2030	ZEV				
	VW	China	50%	PC+LCV	2030	ZEV				
	Audi	Global (excl. China)	100%	PC+LCV	2033	ZEV				
	Skoda	Europe	70%	PC+LCV	2030	ZEV				
	Bentley	Global	100%	PC+LCV	2030	ZEV				
	Porsche	Global	80%	PC+LCV	2030	ZEV				
	Others	/	/	/	/	/				
Ford	All	U.S.	40%	PC+LCV	2030	ZEV	79	89	96	-17
		Leading markets	100%	PC+LCV	2035	ZEV				
BYD	BYD	China	100%	PC+LCV	N/A	ZEV, PHEV	76	70	70	6
Chang'an	All	Global	60%	PC+LCV	2030	ZEV, PHEV	73	66	68	5
SAIC	All	Global	50%	PC+LCV	2025	ZEV, PHEV	73	42	37	36
Tata Motors	Tata Motors	Global	50%	PC	2030	ZEV	71	59	52	19
	Jaguar	Leading markets	100%	PC+LCV	2025	ZEV				
	Land Rover	Leading markets	60%	PC+LCV	2030	ZEV				
	Land Rover	Leading markets	100%	PC+LCV	2035	ZEV				
Honda	All	Global	30%	PC+LCV	2030	ZEV	67	67	73	-4
		Leading markets	80%	PC+LCV	2035	ZEV				
Chery	All	Global	40%	PC+LCV	2030	ZEV, PHEV	58	N/A	N/A	N/A
Hyundai-Kia	Hyundai	Global	34%	PC+LCV	2030	ZEV	54	44	39	15
	Genesis	Global	100%	PC+LCV	2030	ZEV				
	Kia	Global	37%	PC+LCV	2030	ZEV				
Toyota	All	Global	32%	PC+LCV	2030	ZEV	48	44	39	9
Mazda	All	Global	25%	PC+LCV	2030	ZEV	38	34	30	8
Suzuki	All	Japan	20%	PC+LCV	2030	ZEV	32	0	0	32
	All	India	15%	PC+LCV	2030	ZEV				
	All	Europe	80%	PC+LCV	2030	ZEV				
Nissan	All	Global	55%	PC+LCV	2030	ZEV, Hybrid	0	69	60	-60

[a] This number reflects the corrected 2022 score for VW. The previous report overestimated VW's score due to a misinterpretation of the brand coverage of an announced target.

B.6. ZEV INVESTMENT

Table B6

2022 vs. 2023 score comparison and investment components by manufacturer.

OEM	Total ZEV investment (USD millions)	Total mineral investment (USD millions)	Total investment (2023 USD millions)	ZEV multiplier	Investment per vehicle in 2023	2023 score	2022 score adjusted	2022 score	Score changes
Tesla	52,968[a]	0	53,073	1.00	3,740	100	100	100	0
BYD	63,038	55	64,505	0.76	2,535	68	65	79	-11
SAIC	43,350	0	42,699	0.97	2,427	65	71	81	-16
Geely	40,169	0	40,227	0.80	1,677	45	49	46	-1
Mercedes-Benz	45,000	1,210	41,153	0.79	1,567	42	38	34	8
Chang'an	23,425	0	24,563	0.81	1,348	36	61	56	-20
VW	67,409	5,403	69,673	0.82	842	22	25	23	-1
Hyundai-Kia	52,411[b]	0	48,952	0.82	810	21	24	20	1
Tata Motors	11,525[b]	0	10,615	0.72	756	20	21	18	2
Honda	40,000	0	35,377	0.65	734	19	28	24	-5
BMW	17,298[b]	269	18,190	0.77	658	17	22	20	-3
Chery	4,817	0	4,597	0.96	657	17	N/A	N/A	N/A
Mazda	10,600	0	9,518	0.43	559	15	27	25	-10
Renault	6,300	0	6,844	0.95	426	11	25	45	-34
Ford	14,313	3,921	17,594	0.72	413	11	43	36	-25
GM	11,700	549	12,260	0.97	368	10	19	35	-25
Nissan	8,800	0	8,501	1.00	361	9	29	24	-15
Toyota	41,000	126	38,830	0.67	359	9	8	7	2
Stellantis	16,500[b]	175	17,135	0.66	264	7	11	9	-2
Suzuki	14,380	0	13,174	0.30	160	4	0	0	4
Great Wall	1,517	0	1,521	0.74	123	3	6	5	-2

[a] Investment in minerals and charging infrastructure is included in the main ZEV investment amount.
[b] We assumed an equal split of the total investment when a manufacturer's commitment included other future technologies (e.g., autonomous driving technology).

APPENDIX C. METHODOLOGY DETAILS

C.1. REAL-WORLD ELECTRIC DRIVE SHARE ESTIMATION

We estimated real-world electric drive share based on the range of each PHEV model when driving in charge-depleting mode, which is typically related to all-electric range. Data on the all-electric range or charge-depleting mode range for each PHEV model come from the EV specification database that we compiled.

Plötz et al., (2022) and Isenstadt et al. (2022) developed the best-fit curves that reflect the relationship between the charge-depleting range and real-world electric drive share in the European Union and the United States, respectively. Utilizing the range data we compiled as inputs, these curves were the basis for our estimates of real-world electric drive share in all six major markets.

To find the electric drive share of PHEVs in China, India, Japan, Korea, and the United States, we used the function and parameters established by Isenstadt et al. (2022) and applied Equation (2) to each PHEV model. The original function and its coefficients were established by EPA for determining a PHEV model's utility factor (UF), which represents the share of driving performed in charge-depleting (CD) mode.

$$UF = 1 - \left[\exp\left(-\sum_{i=1}^{k}\left(\frac{CD}{ND}\right)^{i} C_i\right)\right] \quad (2)$$

where:

CD = range in CD mode in miles

ND = normalized distance (985 miles, estimated by Isenstadt et al. [2022])

C_i = weighting coefficient (summarized in Table C1)

k = number of coefficients

Using engine-off distance traveled collected by vehicle on-board diagnostics systems on California-based vehicles, Isenstadt et al. (2022) revised the normalized distance (ND) to 985 miles, 2.5 times the default value of 399 miles from EPA, to better reflect the real-world electric drive share of U.S. PHEVs. The other coefficients are displayed in the table below.

Table C1
Electric drive share coefficients established by EPA.

Coef (C_i)	1	2	3	4	5	6	7	8	9	10
Electric drive share for city or highway	13.1	-18.7	5.22	8.15	3.53	-1.34	-4.01	-3.9	-1.15	3.88

We used the same revised parameters from Isenstadt et al. (2022) for China, India, Japan, and Korea, as there is no recent study available targeting these countries. The U.S. PHEV function is from the most recent study on real-world PHEV use, and the analysis was based on automatically collected, direct measurement of drive share with the engine off. In addition, much like in the United States, these countries are primarily dominated by private cars and not the company-owned vehicles that are more common in Europe.

To find the real-world electric drive share of PHEVs in the European Union, we used the function and parameters established by Plötz et al. (2022) and applied Equation (3) to each PHEV model. The original function and its coefficients were established by the European Commission in 2017 to determine a PHEV model's UF, and the functional form is identical to the function used by EPA but with different weighting coefficients.

$$UF = 1 - \left[\exp\left(-\sum_{i=1}^{k}\left(\frac{CD}{ND}\right)^{i} C_i\right)\right] \tag{3}$$

where:

CD = WLTP CD mode range in km

ND = Normalized distance (2,200 km for private or 9,100 km for company cars, estimated by Plötz et al. [2022])

C_i = weighting coefficient (summarized in Table C2)

k = number of coefficients

Table C2
Electric drive share coefficients established by the European Commission.

Coef (C_i)	1	2	3	4	5	6	7	8	9	10
Electric drive share for city or highway	26.3	-38.9	-631.05	5964.8	-25095	60380	-87517	75514	-35749	7155

Plötz et al. (2022) revised the normalized distance (ND) and this parameter was estimated separately for private cars and company cars. The authors adjusted ND = 2,200 km for private vehicles and ND = 9,100 km for company vehicles, 2.8 and 11.4 times the default value of 800 km from the European Commission. According to their estimation, electric drive share is significantly lower for company cars. Because our data do not differentiate ownership type, we assumed a 70% and 30% mix between company and private cars for vehicles sold in the European Union (Krajinska, 2023).

C.2. CLASS COVERAGE CATEGORIZATION USING ICEV-EQUIVALENT CURB WEIGHT

We divided the ZEVs in the sales dataset into eight classes based on vehicle length for PCs and curb weight for LCVs. We used adjusted curb weight for LCV classification. BEVs tend to weigh more because of their batteries, and this can result in inaccurate categorization when directly mapping them into classes designed for ICEVs based on curb weight. To ensure accurate comparisons, we adjusted the curb weight of BEVs to their ICEV counterparts.

To make this adjustment, we obtained curb weight information for 10 ICEV models with a ZEV counterpart with an almost identical size. We only selected as example models ICEVs with a ZEV counterpart produced by the same manufacturer and where that manufacturer is among the top 21 manufacturers included in this report. The ZEV models include both BEVs and FCEVs. The ICEVs' curb weights range from 1,393 kg to 2,261 kg, and the ZEVs' curb weights range from 1,685 kg to 2,558 kg. The ratio between each ICEV and its ZEV counterpart was calculated and resulted in an average ratio of 0.83, which was consistent across models of different curb weights and power trains (standard deviation of 0.034). This average ratio was used as a discount factor to estimate the ICEV-equivalent curb weight of each BEV model, which was found to be a reasonable estimation method for ZEV models with a wide range of curb weights.

Table C3
Curb weight comparison.

OEM	ICEV		ZEV		Ratio	ICEV-equivalent curb weight (kg)
	Model	Curb weight (kg)	Model	Curb weight (kg)		
Kia	Niro	1,393	Niro EV	1,688	0.83	1,405
Hyundai	Kona	1,409	Kona Electric	1,685	0.84	1,403
Toyota	Avalon	1,619	Mirai (FCEV)	1,930	0.84	1,607
BMW	4	1,623	i4	2,123	0.76	1,768
VW	Tiguan	1,708	ID.4	2,072	0.82	1,725
Audi	Q5	1,850	Q4 e-tron	2,120	0.87	1,765
BMW	7	2,141	i7	2,684	0.80	2,235
Mercedes Benz	S class	2,150	EQS	2,539	0.85	2,114
BMW	X5	2,190	iX	2,617	0.84	2,179
Ford	Ford Transit	2,261	Ford E-Transit	2,558	0.88	2,130
Average					**0.83**	

We classified all PCs into five classes (subcompact car, compact car, midsize car, large car, and SUV/MPV) and all LCVs into three classes (small, medium, and large). The length thresholds for PC classification are based on EV-Volumes' global segment classification (EV-Volumes, 2023), and curb weight thresholds for LCV classification are based on the EU N1 subclasses standard for LCV (Regulation 715/2007, 2007). We combined mini passenger cars and the subcompact classes to reflect the model availability in the smaller passenger car segment. The detailed weight thresholds are listed in Table C4.

Table C4

ZEV class categorization.

Fleet	Class	Standards: Length (m)	Source
PV	PC – Mini/subcompact	0 – 4.1	Adapted from EV-Volumes classification[a]
	PC – Compact	4.1 – 4.6	
	PC – Midsize	4.6 – 4.8	
	PC – Large	4.8 -	
	PC – SUV/MPV	N/A	
Fleet	Class	Standards: Curb weight (kg)	Source
LCV	LCV – Small	0 – 1305	EU N1 subclasses
	LCV – Medium	1,305 – 1,760	
	LCV – Large	1,760 – 3,500[b]	

[a] From EV-Volumes, https://www.ev-volumes.com/.
[b] The upper threshold is 3,500 kg for non-U.S. LCVs and 3,856 kg for U.S. LCVs based on the different regulatory categorization in the United States.

C.3. ENERGY CONSUMPTION ADJUSTMENT

We adjusted the energy consumption of each BEV model to account for weight differences, which inherently affect vehicle energy consumption from a physical perspective. To study the relationship between energy consumption and curb weight, we follow Equation (4) and perform a linear regression analysis, using all BEV models sold by the top 21 manufacturers (536 models).

$$EC = \alpha + \beta \times Curb\ weight + \varepsilon \qquad (4)$$

Here, α is a constant, ε is the error term, and β is the coefficient that estimates on average how much energy consumption will increase for every additional kilogram in curb weight. Our analysis shows that α=45.4, β=0.052 (significant at 0.001 level) with a R-sq of 0.35. Such result indicates that, on average, each kilogram increase in curb weight is correlated with a 0.052 $Wh{\cdot}km^{-1}$ increase in energy consumption. This finding is similar with a previous study (Weiss et al., 2020), which investigated 218 electric passenger cars from China, Norway, and the United States and found a correlation of 0.06 $Wh{\cdot}km^{-1}{\cdot}kg^{-1}$.

C.4. CHARGER DEFINITIONS

We categorize chargers as either normal or fast using the criteria below.

Table C5

Charger type definitions.

Type of charger	Power output	Time for charging	Current type
Normal charger	3–7 kW	Slow charging: 7–16 hours (0%–100%)	Alternative current
	11 kW–22 kW	Intermediate charging: 2–4 hours (0%–100%)	Alternative current
Fast charger	50 kW–100 kW	Fast charging: 30–40 minutes (10%–80%)	Direct current
	100+ kW	Ultra fast	Direct current

Source: Adapted from European Court of Auditors. (2021).


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