THE ENVIRONMENT AND THE AUTOMOBILE INDUSTRY

1 Introduction

Automobile sales volume in 2022 was approximately 420 million vehicles, intensifying the decline observed over the last few years. This primarily stemmed from supply side semiconductor and other issues and cannot be attributed to lower demand. However, the situation resulted in China, which had long ranked third in in vehicle sales just behind the U.S., to slide down to fourth place as India jumped ahead. Of those sales, 5.8 million vehicles consisted of battery electric vehicles (BEVs). While this represents only approximately 1.7% of passenger vehicles, it is also a 2.7 times increase over the preceding year, and both the number of units and the rate of increase exceed those of the previous year. Further increase is anticipated, but the value of 1.7% remains far lower than figures in Europe and the U.S.

This article addresses environmental performance topics such as the extent to which environmental standards have been achieved, overall carbon neutrality trends through the year, and a subset of new vehicle models released in 2022.

2 Overview of Atmospheric Environment

Looking at air pollution conditions in 2021, nitrogen dioxide (NO_2), suspended particulate matter (SPM), and particulate matter (PM 2.5) each fully met the environmental standards at all roadside air pollution monitoring stations. In 2020, NO_2 and SPM had also fully met the standards. However, PM 2.5 had failed at four of the 237 stations, but fully met them in 2021. Automobile emissions regulations and other measures were intended to achieve the environmental standards, and can be said to have accomplished their purpose. In that context, it will be interesting to look into the effectiveness and impact of regulations and other measures based on the achievement of the standards.

Table 1 shows the highest ranking stations (roadside air pollution monitoring stations) with a daily nitrogen oxide average in the annual 98th percentile. The regulatory values range from 0.04 to 0.06 ppm or less, and as stated above, those values are met at all stations. Points of particular interest include the fact that, with the exception of the station in Hokkaido, 14 of the 15 listed stations are in a region covered by the legislation on NO_x and PM, and the inclusion among the top ranking stations of Matsubarabashi at Kannana-dori, Ikegami Shinden, and other stations where achieving the standards had always been difficult. This is attributed to the effectiveness of various antipollution measures centered around regulations on new vehicle emissions.

The picture is completely different when it comes to PM 2.5. Table 2 shows the highest ranking stations (roadside air pollution monitoring stations) with a daily particulate matter (PM 2.5) average in the annual 98th percentile. Of the eleven stations in this list the eight stations other than the three in Osaka and Hyogo are in regions not covered by the legislation on NO_x and PM. The Matsubarabashi monitoring station, which is located in Tokyo and is representative of stations for major urban roads where many diesel vehicles congregate, as well as other city center monitoring stations, are completely absent from the list. One explanation is the progress of the switch to vehicles compliant with the new regulations stemming from the legislation on NO_x and PM (vehicles equipped with a diesel particulate filter (DPF) that is particularly effective at reducing PM), which contributes significantly to reducing PM 2.5. If we envision a scenario in which the legislation on NO_x and PM never came into effect, the 80% or so of the regulatory value (35 mg/m^3) result for regions not covered by the law in Table 2 suggest that in places such as city centers, depending on location, achieving the environmental standards would have proven difficult.

The legislation on NO_x and PM also mandates that existing vehicles be either replaced with new vehicles or

Table 1 Highest Ranking Stations with NO_2 Daily Average in Annual 98th Percentile (Roadside Air Pollution Monitoring Stations)

Station name	Prefecture	Municipality	98th percentile (ppm)	Environmental standard
Matsubarabashi, Kannana-dori	Tokyo	Ota-ku	0.051	Achieved
Mukogawa	Hyogo	Amagasaki	0.048	Achieved
Ikegami Shinden Koen-mae	Kanagawa	Kawasaki-ku, Kawasaki-shi	0.047	Achieved
Yamatocho, Nakasendo	Tokyo	Itabashi-ku	0.046	Achieved
Hinode, Funabashi-shi (vehicles)	Chiba	Funabashishi	0.045	Achieved
Dekijima Elementary School	Osaka	Osaka-shi	0.043	Achieved
Higashi 18-chome	Hokkaido	Higashi-ku, Sapporo-shi	0.042	Achieved
Imazato Intersection	Osaka	Higashinari-ku, Osaka-shi	0.042	Achieved
Kita 19-jo	Hokkaido	Kita-ku, Sapporo-shi	0.041	Achieved
Tatsumi, Mitsume-dori	Tokyo	Koto-ku	0.041	Achieved
Nakahara-guchi Intersection	Tokyo	Shinagawa-ku	0.041	Achieved
Osakabashi, Yamate-dori	Tokyo	Meguro-ku	0.041	Achieved
Ohara, Koshu Kaido	Tokyo	Shibuya-ku	0.041	Achieved
Endo-machi Intersection	Kanagawa	Saiwai-ku, Kawasaki-shi	0.041	Achieved
Futago	Kanagawa	Takatsu-ku, Kawasaki	0.041	Achieved

Table 2 Highest Ranking Stations with PM 2.5 Daily Average in Annual 98th Percentile (Roadside Air Pollution Monitoring Stations)

Station name	Prefecture	Municipality	Annual 98th percentile (mg/m^3)	Environmental standard
Suido-cho roadside air pollution monitoring stations	Kumamoto	Chuo-ku Kumamoto	29.9	Achieved
Koga	Fukuoka	Koga-shi	29.1	Achieved
Suita Summary Court	Osaka	Suita-shi	27.6	Achieved
Nagatsu	Okayama	Hayashima-cho	27.6	Achieved
Abiko Junior High School	Osaka	Sumiyoshi-ku, Osaka	26.5	Achieved
Ohashi	Fukuoka	Minami-ku, Fukuoka	26.5	Achieved
Fukuishi	Nagasaki	Sasebo-shi	26.4	Achieved
Mojiko roadside air pollution monitoring stations	Fukuoka	Moji-ku, Kitakyushu-shi	26.2	Achieved
Yatsushiro roadside air pollution monitoring station	Kumamoto	Yatsushiro	26.I	Achieved
Hiraoka	Hyogo	Kakogawa-shi	25.8	Achieved
Chidoribashi	Fukuoka	Hakata-ku, Fukuoka	25.8	Achieved

retrofitted with emissions reduction devices, depending on the emissions regulations that require compliance. These requirements differ from the conventional fairness-centered approach that involved measures such as limiting the applicable areas. Looking at things now, some 20 years after the law came into effect, the situation described above shows that achieving the environmental standards in cities would have been uncertain without the legislation on NO_x and PM. However, outside of cities, those standards were met even without that legislation, which can therefore likely be classified as a necessary and sufficient measure.

In contrast, the transportation sector emitted 185 million tons (after the distribution of electricity and heat) of CO_2, which makes up the majority proportion of greenhouse gases, in 2021, an increase of 0.8% from 2020. This accounts for 17.4% of all emissions in the transportation sector. At −17.6% compared to 2013, it also represents ongoing improvement. The recovery of socioeconomic activity since the major 10.2% decrease between 2019 and 2020 due to reduced activity stemming from measures to prevent the spread of COVID-19 accounts for the slight resulting increase in CO_2.

3 Major Environmental Events in 2022

This section presents several environment-related topics from 2022.

A new test to measure the particle number (PN) during periodic inspections of diesel vehicles was added in Belgium in July, and then in Switzerland and the Netherlands in January 2023. It is scheduled to be added in Germany and other countries as well. The results of mea-

surements taken over two months in Belgium after the introduction of the test were presented to the GRPE working group, which is responsible for, notably, emissions test methods within the WP.29 United Nations forum that discusses international certification standards for automobiles. The results showed that 6.76% of vehicles exceeded the one million particles per cc set as the threshold for a DPF malfunction. The results include cases where users deliberately removed the DPF and therefore do not mean all DPF had degraded. Nevertheless, measurements taken from 313,615 vehicles made it clear that DPF performance had degraded in a significant number of vehicles and may have an impact in areas such as durability tests or performance maintenance measures for vehicles in use.

In the context of the very difficult to achieve electrification of commercial vehicles, the CJPT venture invested in by Toyota, Isuzu, Suzuki, and Daihatsu announced in July that it would work with other partners and organizations on the building and social implementation of energy management systems in Fukushima and Tokyo to increase the adoption of electric vehicles. They aim to introduce approximately 580 electric vehicles in the form of heavy-duty FC trucks for the Tohoku–Kanto–Kansai transportation artery, and light-duty commercial EVs for last mile services. The slow start compared to the already more than 10,000 EV and FCV trucks sold nationwide in China in 2021 is irrefutable. However, the venture partners include many major corporations, and advancing electrification in conjunction with an energy management system that accounts for transportation legislation and commercial traditions in Japan is expected to develop into a highly effective approach in the long term.

In July, BYD Japan Co., Ltd., the Japanese arm of the Chinese BYD, announced its entry into the Japanese market. The mid-size Atto 3 SUV and two other models, all of them EVs, will gradually go on sale starting in January 2023. With many Japanese automakers crowding the domestic market, there is very little room for manufacturers from outside Japan, as attested by Tesla being essentially alone in having made its presence felt in the market over the last 20 years or so. However, BYD is a global EV manufacturer, and has already delivered many vehicles such as electric buses to Japan. This difference from mere new participation in the market will draw attention for some time.

In November, the European Commission released a proposal for Euro 7, the next stage of environmental regulations. Representing a paradigm shift in the approach to regulations, the proposed changes include replacing laboratory chassis dynamometer tests with emissions evaluations centered around testing real driving emissions (RDE), adding new regulated components such as ammonia for light- and medium-duty vehicles, nitrous oxide (N_2O) for heavy-duty vehicles, and formaldehyde, as well as adding battery deterioration and on-board monitoring (OBM) functions. Although the details have yet to be finalized, the new regulation is expected to significantly impact no just technical development, but also market trends.

In December, the Nissan Sakura and Mitsubishi eK Cross EV were announced as the winners of the 2022–2023 Car of the Year Japan award. Similarly, among imported vehicles, the Ioniq 5 was selected as the Imported Car of the Year while the BMW iX was chosen for the Design Car of the Year award. Both vehicles are EVs, and while EVs have received an award in the past, this marks the first time they received awards in more than one category. These examples illustrate how EVs have become more than just "environmentally friendly", and are gradually rivaling or exceeding existing internal combustion engine vehicles in terms of performance and other aspects of product appeal.

In Europe, a ban on sales of non-zero CO_2 emission vehicles—effectively a ban on sales of internal combustion engine vehicles—starting in 2035 has been declared. However, at the EU Council of Energy Ministers held on March 28, 2023, the European Commission reached an agreement on allowing sales of internal combustion engine vehicles limited to vehicles using synthetic fuels produced through a carbon neutral process. The exemption only applies to synthetic fuels and does not extend to biofuels. Reducing the price and increasing the adoption of carbon neutral synthetic fuels is expected to prove a considerable challenge. The exemption should therefore not be viewed as a measure that will result in a high number of internal combustion engine vehicles remaining in use in the EU, but rather as a measure that addresses the reality of uses and categories that are not amenable to EV-based business models.

4 Trends in Environmentally Friendly Technologies Seen in Models Released in 2022

This section presents the subset of models released in 2022 most likely to attract attention with respect to fuel efficiency and other areas of performance. The specifications for fuel economy values and the pictures are taken from manufacturer press releases, as well as catalog information, including information released on the Web. Unless otherwise indicated, fuel economy and cruising range on a single charge are those of the WLTC, and values with ranges depend on equipment and grade.

The Toyota bZ4X (Fig. 1) and the Subaru Solterra were announced in April and May. These represent the first foray into the general EV market by Toyota (excluding the Lexus brand) and Subaru. However, for purposes of battery recycling management and residual value, as well as to eliminate maintenance concerns, the bZ4X is not available through ordinary sales and is only offered through the subscription service known as Kinto. The main performance specifications are the installation of a 71.4 kWh lithium-ion battery, front and rear drive motors of 80 kW in the 4WD model and 150 kW in the front-wheel drive model, and a cruising range of 487 to 559 km on a single charge. The 128 Wh/km alternating current consumption of the front-wheel drive model is close to the level of the Sakura presented later, and constitutes excellent mileage (electric power consumption). Despite the expectations for such a high performance model, recalls on the wheel hub bolts immediately after the launch of the vehicle led to a temporary halt in shipments.

In May, the Nissan Sakura (Fig. 2) and Mitsubishi eK Cross EV mini-vehicle EVs were announced. Mini-vehicles generally see little use on expressways and often serve as a means of transportation in the regions, making them a category that can take advantage of the characteristics of EVs. This model is an answer to such latent demand. Its cruising range on a single charge, the key point for EVs, is 180 km. Although short compared to EVs already on the market, it likely represents a decision to compromise between the increased cost and weight associated with adding more batteries and the level that provides an optimal solution for the majority of envisioned uses. That decision appears to have been spot on, as the company announced in June that "orders had exceeded 11,000 vehicles approximately three weeks after the release" of the vehicle, which represents a significant contribution to the dramatic increase in EV sales noted at the beginning of this article.

In July, Renault started selling its Lutecia hybrid model in Japan (Fig. 3). It is the only imported vehicle equipped with a full hybrid system, which combines a 4-cylinder 1.6-liter gasoline engine with a 36 kW main motor as well as a 15 kW starter generator motor, and uses a lithium-ion battery. Fuel efficiency, a focal point, is 25.2 km/L, a level difficult to achieve for the mild hybrid models often seen in European vehicles, and the best fuel efficiency available in imported Renault vehicles.

In July, Nissan announced a new X-Trail model (Fig. 4). Nissan has been raising the performance of its e-Power series hybrid system. In addition to using a 1.5-liter engine equipped with a VC turbocharging system featuring a variable compression ratio mechanism to generate

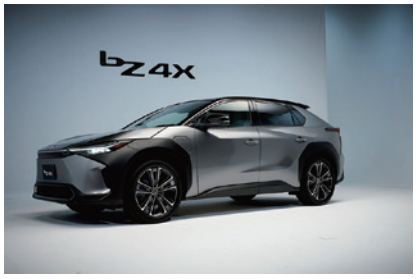

Fig. 1 Toyota bZ4X

Fig. 2 Nissan Sakura

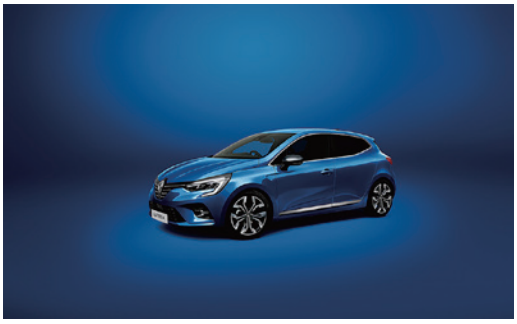

Fig. 3 Renault Lutecia

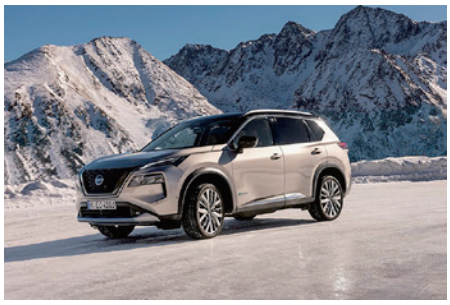

Fig. 4 Nissan X-Trail

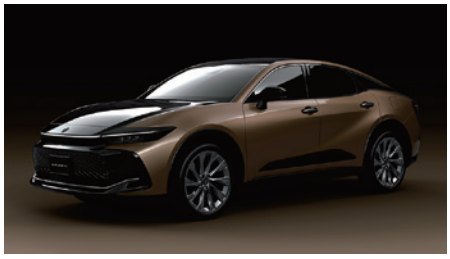

Fig. 5 Toyota Crown

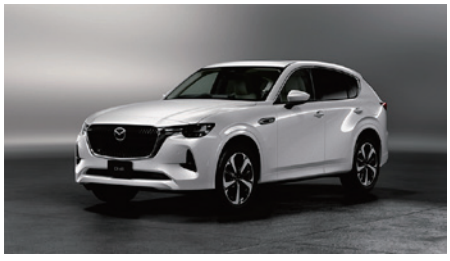

Fig. 6 Mazda CX-60

electricity, this model achieves high driving performance through the e-4orce system, which takes advantage of series hybrid characteristics to achieve momentary integrated control of the motors at the front and rear, as well as the brakes on all four wheels. In a category filled with rivals, Nissan appears to have loaded the model with its latest technology. The model equipped with the e-4orce system have a fuel efficiency of 18.3 to 18.4 km/L.

Toyota brought out a fully redesigned Crown in July (Fig. 5). Although an upcoming sedan model was also announced, this model is a crossover—a high ground clearance vehicle similar to an SUV. Two powertrains, both 4-wheel drive, are available: a 2.4-liter turbocharged engine paired with a new hybrid system, and a hybrid system that uses a 2.5-liter gasoline engine. The 2.5-liter model, which features a bipolar nickel hydrogen battery and a front grille radiator, has a fuel efficiency of 22.4 km/L. Achieving an improvement of over 10% in fuel efficiency using a powertrain comparable to that of the

Fig. 7 Toyota Prius

previous front-engine, rear-wheel drive model, which had a smaller front projected surface area and a fuel efficiency of 20.0 km/L, speaks to the ongoing evolution of the technology.

In September, Mazda announced the launch of a new CX-60 model (Fig. 6). While it also offers a 2.5-liter gasoline engine and PHEV powertrain options, all eyes are turned toward the newly developed 6-cylinder 3.3-liter diesel engine. Air flow is the key point in diesel engine performance. For both the EGR and the supercharger, higher air flow levels broaden the control range and help enhance performance. This engine allocates the increased air flow obtained from adopting six cylinders to output, emissions, and fuel efficiency. In addition to the already adopted premixing combustion, a dual zone egg-shaped combustion chamber providing additional spatial control was adopted as a technology to meet emissions regulations without a NO_x aftertreatment device. At the same time, the maximum average effective pressure was lowered compared to previous models to address the difficulties faced by EGR at high loads and high air flow volumes. An enhanced compression ratio and the use of steel pistons also reduce cooling loss, resulting in better fuel efficiency. The mild hybrid model fuel efficiency of 21.0 to 21.1 km/L is equivalent to mini-vehicles in terms of numbers. This makes it a model offering a high level of environmental performance while maintaining an output performance worthy of the high grade models Mazda refers to as the Large Product Group.

Toyota launched its fully redesigned Prius in January 2023 (Fig. 7). Until now, the Prius has projected an image centered on environmental performance stemming from its hybrid system and other cutting edge technologies to improve fuel efficiency. However, this new model shits its emphasis to style and driving performance. This is symbolized by the 144 kW maximum system output of the 2-liter hybrid model, a value 1.6 times higher than the previous version. The 28.6 km/L fuel efficiency (front

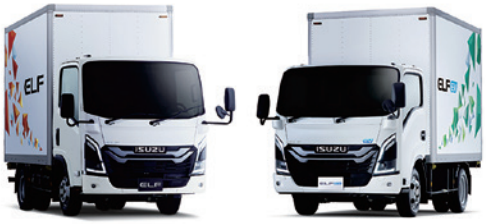

Fig. 8 Isuzu Elf (EV on the right)

wheel drive model) exceeds the 27.2 km/L of the Prius A Touring Selection (front wheel drive model), which focused on driving performance. One technological element contributing to that improvement is the choice of tires. The previous Touring Selection model used size 215/45R17 tires, while the new model uses size 195/50R19 tires. The adoption of the Bridgestone ologic technology, which reduce air and rolling resistance by narrowing the width and increasing the diameter of the tire while securing grip, often a conflicting component, is thought to contribute to achieving both driving and environmental performance.

Isuzu announced a fully redesigned Elf in March (Fig. 8). The first Isuzu mass production EV, the Elf EV, was added to the lineup to complement the normal diesel truck. The Elf EV uses two or three 20 kWh modular battery packs to address the variety of vehicle types and usages found in commercial vehicles. At the same time, is adopts a heat pump-based air conditioning system and features seat heaters as standard equipment to reduce the energy consumption of the interior air conditioner. In contrast, the key point of the diesel model is undoubtedly the installation of the effectively 9-speed DCT ISIM transmission. This may seem excessive given that trucks with a carrying capacity of two to three tons generally have 5- or 6-speed transmissions even for automatic transmissions. However, considering that EVs such as the one above will become more prevalent for very short distance usages, it is very likely that even light-duty diesel vehicles will be expected to have better fuel efficiency than ever, making the introduction of technology with a high potential a sound decision. In terms of that fuel efficiency, all models meet the 2025 fuel economy standards, and variants equipped with a start-stop system even exceed those standards by 5 to 15%, depending on category, suggesting that the improvement obtained from the ISIM is significant.

5 Summary

There is no doubt that electrification, which is already underway, will form the basis of automobile carbon neutrality. That is because electricity represents the form of energy with the highest potential to achieve carbon neutrality. However, the best energy sources in terms of ease of storage and energy density are, in order, liquids, liquefied gas, gases, and electricity. Consequently, electrification does not follow the same linear pattern as the progression that saw steam locomotives replaced by diesel, and then electric locomotives in the past. That may be why there have been many published examples of research on internal combustion engines using hydrogen or ammonia (in liquefied gas form). Regardless of what fuel is used and whether it is used in large or small quantities, internal combustion engines will always have to wrestle with the emission of harmful substances such as NO_x or PM. Air pollution remains a problem in parts of Europe and the U.S. state of California, prompting calls for reducing NO_x and other substances even further. In contrast, as noted in the introduction, Japan has achieved its environmental standards and is comparatively better prepared to study the use of internal combustion engines that rely on alternatives such as ammonia. It seems safe to say that Japan is in a good position to take a more proactive role in selecting what approaches to take to achieve the goal of carbon neutrality. Once achieved, measures that properly tackle various issues, such as the legislation on NO_x and PM, will hopefully have complemented stricter regulations for new vehicles in contributing to the process of reaching that goal.

References

- https://unece.org/sites/default/files/2023-01/GRPE-87-36r1e.pdf
- https://blog.evsmart.net/ev-news/overview-chinas-new-energy-heavy-duty-truck-market-in-2021/
- https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6495