# HYBRID VEHICLES, ELECTRIC VEHICLES, FUEL CELL ELECTRIC VEHICLES

## 1 Hybrid Vehicles

### 1. 1. Introduction

As automotive emissions regulations grow increasingly stringent, improving fuel efficiency has become an urgent task. As one way of realizing this objective, automakers have been developing hybrid electric vehicles (HEVs) that combine an internal combustion engine (ICE) with motors. The number of plug-in hybrid vehicles (PHEVs), which allow external charging of the on-board storage battery that powers the motors (i.e., the traction battery), is also increasing. This section describes the current status of HEV and PHEV popularization in Japan, as well as recent trends in research, development, and standardization related to electrified vehicles.

### 1. 2. Popularization of HEVs and PHEVs in Japan

Figure 1 shows that the number of HEVs and PHEVs on the road in Japan is increasing year after year. In 2021, the number of passenger HEVs on the road in Japan (excluding mini-vehicles) increased by around 768,000 vehicles from 2020 to reach approximately 10,631,000 vehicles. This is roughly 27.1% of the total number of passenger vehicles (39,182,000 vehicles) on the road, excluding mini-vehicles. The number of mini HEVs on the road in Japan in 2021 increased by approximately 367,000 vehicles from 2020, and now stands at around 2,322,000 vehicles. This is roughly 10.2% of the total number of mini-vehicles (22,736,000 vehicles) on the road. In addition, the number of passenger PHEVs has also continued to increase since 2009. In 2021, the number of PHEVs on the road increased by approximately 23,000 from 2020 to reach around 174,000 vehicles. This is roughly 0.4% of the total number of passenger vehicles on the road, excluding mini-vehicles.

### 1. 3. New HEVs and PHEVs Launched in Japan in 2022

Excluding mild hybrid electric vehicles (MHEVs) that are equipped with a motor that supports the ICE but cannot be used exclusively to drive the vehicle, thirteen HEV models were launched by Japanese automakers and two HEV models were launched by non-Japanese automakers in Japan in 2022. Similarly, Japanese automakers launched four MHEV models and three PHEV models, whereas non-Japanese automakers launched fourteen MHEV models and seventeen PHEV models in Japan in 2022.

Table 1 lists the PHEVs launched in Japan in 2022 according to the date sales began. The main trends were as follows.

In January, Volvo launched the S60 Recharge, V60 Recharge, XC60 Recharge, V90 Recharge, and XC90 Recharge, and Land Rover launched the Range Rover P440e and Range Rover P510e. The five models launched by Volvo combine a 2.0-liter inline 4-cylinder turbocharged engine with motors at both the front and rear wheels. The power of the motor at the rear wheels is approximately 65% higher and the capacity of the traction battery is approximately 60% higher than the previous model. The system supports normal AC charging up to 3.7 kW. The Range Rover P440e and Range Rover P510e combine a 3.0-liter inline 6-cylinder engine with a motor. The PHEV system in these models supports normal AC

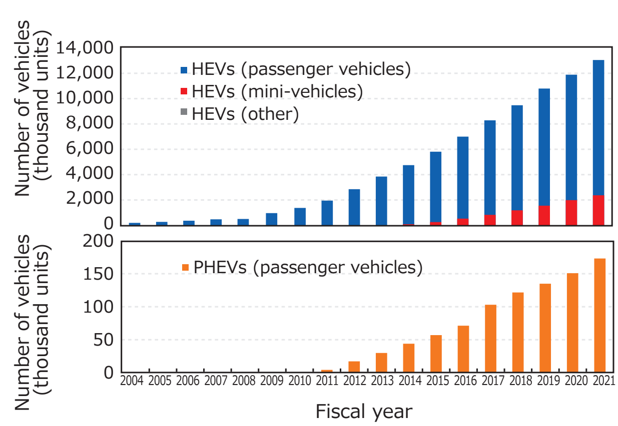


**Fig. 1** Trends in the Number of HEVs and PHEVs on the Road in Japan

**Table 1** Main PHEVs Launched in Japan in 2022

| Date announced/went on sale | | 2022/1/13 | 2022/1/13 | 2022/1/17 | 2022/4/5 | 2022/4/9 |
|---|---|---|---|---|---|---|
| Company | | Volvo | Volvo | Land Rover | Volkswagen | DS Automobiles |
| Name | | S60, V60/XC60 (Recharge) | V90/XC90 (Recharge) | Range Rover (P440 e/P510 e) | Passat GTE Variant | DS 9 E-Tense |
| Driving wheels | | All | All | All | Front wheels | Front wheels |
| Fuel efficiency (WLTC, km/L) | | 15.6/14.3 | 14.5/13.3 | — | 15.9 | 15.8 |
| Converted EV driving distance (km) | | 91.0/81.0 | 81.0/73.0 | — | 57.0 | 65.0 |
| Engine | Fuel | Gasoline | Gasoline | Gasoline | Gasoline | Gasoline |
| | Displacement (cc) | 1,968 | 1,968 | 2,996 | 1,394 | 1,598 |
| | Maximum power (kW) | 186 | 233 | 324 / 375 | 115 | 147 |
| | Maximum torque (Nm) | 350 | 400 | 620 / 700 | 250 | 300 |
| Motor | Type | AC synchronous (front and rear) | AC synchronous (front and rear) | — | AC synchronous | AC synchronous |
| | Rated power (kW) | 32.5 (front) 99.0 (rear) | 32.5 (front) 99.0 (rear) | — | 55 | 30 |
| | Maximum power (kW) | 52 (front) 107 (rear) | 52 (front) 107 (rear) | — | 85 | 81 |
| | Maximum torque (Nm) | 165 (front) 309 (rear) | 165 (front) 309 (rear) | — | 330 | 320 |
| Battery | Type | Lithium-ion | Lithium-ion | — | Lithium-ion | Lithium-ion |
| | Total voltage (V) | 369.0 | 369.0 | — | 352.0 | 300.2 |
| | Capacity (kWh) | 18.8 | 18.8 | — | 13.0 | 15.6 |

| Date announced/went on sale | | 2022/4/13 | 2022/4/28 | 2022/6/27 | 2022/10/1 | 2022/10/4 |
|---|---|---|---|---|---|---|
| Company | | Peugeot | DS Automobiles | Mercedes-Benz | Citroen | Toyota |
| Name | | 308 GT Hybrid/ 308 SW GT Hybrid | DS 4 E-Tense | S 580 e 4 Matic Long | C5 X Plug-In Hybrid | RAV4 (PHEV) |
| Driving wheels | | Front wheels | Front wheels | All | Front wheels | All |
| Fuel efficiency (WLTC, km/L) | | 17.6/17.5 | 16.4 | 11.0 | 17.3 | 22.2 |
| Converted EV driving distance (km) | | 64.0/69.0 | 56.0 | 100.0 | 65.0 | 95.0 |
| Engine | Fuel | Gasoline | Gasoline | Gasoline | Gasoline | Gasoline |
| | Displacement (cc) | 1,598 | 1,598 | 2,996 | 1,598 | 2,487 |
| | Maximum power (kW) | 132 | 132 | 270 | 132 | 130 |
| | Maximum torque (Nm) | 250 | 250 | 500 | 250 | 219 |
| Motor | Type | AC synchronous | AC synchronous | AC synchronous (front and rear) | AC synchronous | AC synchronous (front and rear) |
| | Rated power (kW) | 30 | 30 | 55 | 30 | — |
| | Maximum power (kW) | 81 | 81 | 110 | 81 | 134 (front) 40 (rear) |
| | Maximum torque (Nm) | 320 | 320 | 440 | 320 | 270 (front) 121 (rear) |
| Battery | Type | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion |
| | Total voltage (V) | 305.0 | 304.0 | — | 304.0 | 355.2 |
| | Capacity (kWh) | 12.4 | 12.4 | 28.6 | 12.4 | 18.1 |

charging up to 7.0 kW as well as rapid DC charging (CHAdeMO standard).

In April, Volkswagen launched the Passat GTE Variant, DS Automobiles launched the DS 9 E-Tense and DS 4 E-Tense, and Peugeot launched the 308 GT Hybrid and 308 SW GT Hybrid. The Passat GTE Variant is equipped with a 1.4-liter inline 4-cylinder engine and a motor integrated into the gearbox. The traction battery is mounted under the floor and features a capacity approximately 30% higher than the previous model. This system supports normal AC charging. The DS 9 E-Tense combines a 1.6-liter inline 4-cylinder turbocharged engine with a motor installed at the front wheels. This HEV system outputs 184 kW. The traction battery is mounted under the rear seats and the vehicle can be driven up to 135 km/h on motor power alone (in EV mode). This system supports normal AC charging. The DS 4 E-Tense combines a 1.6-liter inline 4-cylinder turbocharged engine with a motor installed at the front wheels. This HEV system outputs 166 kW. The traction battery is mounted under the rear trunk and the vehicle can be driven up to 135 km/h in EV mode. This system supports normal AC charging. The 308 GT Hybrid and 308 SW GT Hybrid combine a 1.6-liter inline 4-cylinder turbocharged engine

Table 1 Main PHEVs Launched in Japan in 2022 (Continued)

| Date announced/went on sale | | 2022/10/4 | 2022/10/24 | 2022/11/18 | 2022/12/14 |
|---|---|---|---|---|---|
| Company | | Toyota | Jeep | Toyota | Jeep |
| Name | | Harrier (PHEV) | Grand Cherokee (Limited 4 xe/Summit Reserve 4 xe) | RX450 h+ | Wrangler Unlimited Rubicon 4 xe |
| Driving wheels | | All | All | All | All |
| Fuel efficiency (WLTC, km/L) | | 20.5 | 10.4 | 18.8 | 8.6 |
| Converted EV driving distance (km) | | 93.0 | 53.0 | 83.0 | 42.0 |
| Engine | Fuel | Gasoline | Gasoline | Gasoline | Gasoline |
| | Displacement (cc) | 2,487 | 1,995 | 2,487 | 1,995 |
| | Maximum power (kW) | 130 | 200 | 136 | 200 |
| | Maximum torque (Nm) | 219 | 400 | 228 | 400 |
| Motor | Type | AC synchronous (front and rear) | AC synchronous (front and rear) | AC synchronous (front and rear) | AC synchronous (front and rear) |
| | Rated power (kW) | — | 20 (front) 47 (rear) | — | 20 (front) 47 (rear) |
| | Maximum power (kW) | 134 (front) 40 (rear) | 46 (front) 107 (rear) | 134 (front) 40 (rear) | 46 (front) 107 (rear) |
| | Maximum torque (Nm) | 270 (front) 121 (rear) | 54 (front) 255 (rear) | 270 (front) 121 (rear) | 54 (front) 255 (rear) |
| Battery | Type | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion |
| | Total voltage (V) | 355.2 | 350.0 | 355.2 | 350.0 |
| | Capacity (kWh) | 18.1 | 14.9 | 18.1 | 15.5 |

Note: "—" denotes that there is no publicly available information.

with a motor installed at the front wheels. This HEV system outputs 166 kW. The traction battery is mounted under the rear seats and the vehicle can be driven up to 135 km/h in EV mode. This system supports normal AC charging.

In June, Mercedes-Benz launched the S 580 e 4Matic Long, which combines a 3.0-liter inline 6-cylinder engine with a motor. This HEV system outputs 375 kW. The vehicle can be driven up to 140 km/h in EV mode, and the system supports normal AC charging up to 6.0 kW as well as rapid DC charging (CHAdeMO standard).

In October, Citroen launched the C5 X Plug-In Hybrid, Toyota launched the RAV4 and Harrier, and Jeep launched the Grand Cherokee Limited 4xe and Grand Cherokee Summit Reserve 4xe. The C5 X Plug-In Hybrid combines a 1.6-liter inline 4-cylinder turbocharged engine with a motor installed at the front wheels. This HEV system outputs 166 kW. The traction battery is mounted under the rear trunk and the vehicle can be driven up to 135 km/h in EV mode. This system supports normal AC charging. The RAV4 and Harrier PHEV models combine a 2.5-liter inline 4-cylinder engine with motors at the front and rear wheels. This HEV system outputs 225 kW. The traction battery is mounted under the floor and the system supports normal AC charging. The Grand Cherokee Limited 4xe and Grand Cherokee Summit Reserve 4xe combine a 2.0-liter inline 4-cylinder turbocharged engine with two motors. This system supports normal AC charging.

In November, Toyota launched the RX450h+, which combines a 2.5-liter inline 4-cylinder engine with motors at the front and rear wheels. This system supports normal AC charging.

In December, Jeep launched the Wrangler Unlimited Rubicon 4xe, which combines a 2.0-liter inline 4-cylinder turbocharged engine with two motors. The traction battery is mounted under the rear seats and the system supports normal AC charging.

### 1.4. Trends in Standardization

The international standardization of electrified vehicles (including HEVs, electric vehicles (EVs), and fuel cell electric vehicles (FCEVs) as well as electrical drive systems and parts is mainly being pursued under the auspices of the Electrically Propelled Vehicles subcommittee of the International Organization for Standardization (ISO TC 22/SC 37). This subcommittee covers the vehicle as a whole, systems, and parts, as well as vehicle requirements related to charging and the performance and safety aspects of secondary batteries. Standardization is currently under way related to the cruising range and power consumption of EVs, the charging performance of EVs and PHEVs, the driving performance of EVs, the driving performance and low-temperature startability of FCEVs, as well as electrical tests for high-voltage system components.

## 2 Electric Vehicles

### 2. 1. Introduction

Electric vehicles (EVs) are attracting attention as extremely quiet environmentally friendly vehicles that emit no harmful tailpipe emissions. However, the proportion of EVs in Japan remains at around 0.2% of all vehicles, indicating that full-scale popularization has yet to be attained. Issues slowing the widespread adoption of EVs include those related to vehicle performance, such as the length of charging times and the short range per charge, those related to infrastructure such as charging facilities, and those related to vehicle price derived from the high cost of traction batteries. The issue of long charging times is being addressed by raising the output of charging standards, and cruising range issues are being addressed by increasing the capacity and power density of the traction battery, and by raising the efficiency of the traction battery, motor, and inverter to improve power consumption. On the infrastructure front, measures are being implemented by the national and some local governments to subsidize the introduction of chargers and the like. The issue of vehicle price is being addressed through the introduction of incentives, and improvements to mass-production technologies to reduce cost.

This section describes the current status of EV popularization in Japan and initiatives to expand the popularity of this category of vehicles.

### 2. 2. Popularization of EVs in Japan

Figure 2 shows the change in the number of EVs on the roads in Japan. The number of EVs in Japan continued to decrease until 2008. However, after the launch of the Mitsubishi i-MiEV in 2009 as the world's first mass-production EV equipped with a large-capacity traction battery, and the Nissan Leaf in 2010, the number of EVs on the road has steadily increased. As of the end of March 2022, the number of passenger EVs on the road in Japan (excluding mini-vehicles) increased by approximately 15,000 vehicles from 2021, and now stands at around 138,000 vehicles. In addition, the number of mini-vehicle EVs on the road increased by approximately 1,000 vehicles and now stands at around 21,000 vehicles. As a result, the number of EVs on the road in Japan (approximately 161,000 vehicles) accounts for roughly 0.2% of the total number of vehicles (approximately 82,078,000 vehicles).

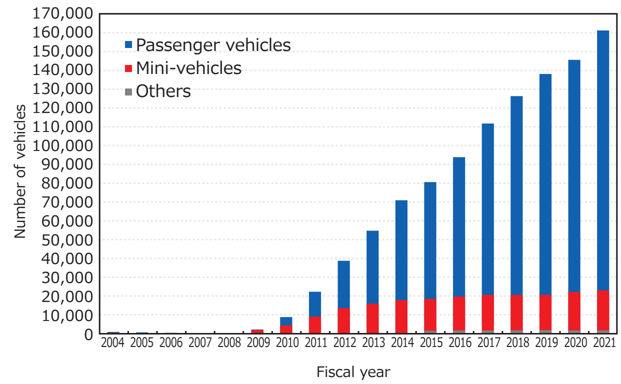


**Fig. 2** Change in the Number of EVs on the Road in Japan (as of the End of March each Year)

### 2. 3. New EVs Launched in Japan in 2022

Japanese automakers launched four EV models and non-Japanese automakers launched sixteen EV models in Japan in 2022. Table 2 lists the EVs launched in Japan in 2022 according to the date sales began. The main trends were as follows.

In January, Citroen launched the Ë -C4 Electric. This model is equipped with a motor at the front wheels. The traction battery assembly consists of 18 modules each weighing approximately 13.1 kg and mounted under the front seats, rear seats, and center console in an H-shaped configuration when viewed from above. The system supports normal AC charging and rapid DC charging up to 50 kW (CHAdeMO standard).

In February, BMW launched the i4 and i4 M50. The i4 is equipped with a motor at the rear wheels. The i4 M50 is equipped with a motor at both the front and rear wheels that deliver a total maximum power of 400 kW. In both models, the traction battery is mounted under the floor. Each system supports normal AC charging up to 6.4 kW and rapid DC charging up to 150 kW.

In May, Hyundai launched the Ioniq5, Toyota launched the bZ4X, Subaru launched the Solterra, and BMW launched the iX M60. The Ioniq5 is equipped with a motor at both the front and rear wheels that deliver a total maximum power of 225 kW. The traction battery is mounted under the floor and the system supports both normal AC charging and rapid DC charging (CHAdeMO standard). The bZ4X and Solterra were jointly developed by Toyota and Subaru, and feature an eAxle that integrates the motor, transaxle, and inverter. Front-wheel-drive versions of both models have one eAxle at the front wheels, while four-wheel-drive versions have an eAxle at both the front and rear wheels that deliver a total maximum power of 160 kW. The traction battery in these models is mounted under the floor and both systems support normal AC charging up to 6.6 kW as well as rapid DC charging up to 150 kW(CHAdeMO standard). The iX M60 is equipped with a motor at both the front and rear wheels that deliver a total maximum power of 455 kW. The traction battery is mounted under the floor and the system supports both normal AC charging and rapid DC charging (CHAdeMO standard).

In June, Tesla launched the Model Y, Nissan launched the Sakura, Mitsubishi launched the eK Cross EV, and Fiat launched the 500e. Front-wheel-drive versions of the Model Y have one motor at the front wheels, while four-wheel-drive versions have a motor at both the front and rear wheels. In both versions, the traction battery is mounted under the floor. Each system supports normal

**Table 2** Main EVs Launched in Japan in 2022

| | | 2022/1/22 | 2022/2/16 | 2022/5/2 | 2022/5/12 | 2022/5/12 | 2022/5/24 |
|---|---|---|---|---|---|---|---|
| Date announced/went on sale | | 2022/1/22 | 2022/2/16 | 2022/5/2 | 2022/5/12 | 2022/5/12 | 2022/5/24 |
| Company | | Citroen | BMW | Hyundai | Toyota | Subaru | BMW |
| Name | | Ë-C4 Electric | i4/i4 M50 | Ioniq 5 | bZ4 X | Solterra | iX M60 |
| Driving wheels | | Front wheels | Rear wheels/all wheels | Rear wheels | Front wheels/all wheels | Front wheels/all wheels | All |
| AC power consumption rate (WLTC, Wh/km) | | 140 | 157 / 173 | 131 | 128 / 134 | 126 / 133 | 199 |
| Cruising range on a single charge (WLTC, km) | | 405 | 604 / 546 | 498 | 559 / 540 | 567 / 542 | 615 |
| Motor | Type | AC synchronous | AC synchronous (front and rear) | AC synchronous | AC synchronous (front and rear) | AC synchronous (front and rear) | AC synchronous (front and rear) |
| | Rated power (kW) | 57 | 105/70 (front)<br>95 (rear) | — | — | 73/59 (front)<br>59 (rear) | 70 (front)<br>125 (rear) |
| | Maximum power (kW) | 100 | 250/190 (front)<br>230 (rear) | 125 | 150/80 (front)<br>80 (rear) | 150/80 (front)<br>80 (rear) | 190 (front)<br>360 (rear) |
| | Maximum torque (Nm) | 260 | 430/365 (front)<br>430 (rear) | 350 | 266/169 (front)<br>169 (rear) | 266/169 (front)<br>169 (rear) | 365 (front)<br>650 (rear) |
| Battery | Type | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion |
| | Total voltage (V) | 400.0 | 399.0 | 523.0 | 355.2 | 355.2 | 369.0 |
| | Capacity (kWh) | 50.0 | 83.9 | 58.0 | 71.4 | 71.4 | 111.5 |
| Charging time | Normal charging (h) | 18 (3 kW)<br>9 (6 kW) | 15 (6.4 kW) | 9.75 (6 kW)* | 21 (3 kW)<br>12 (6 kW) | 21 (3 kW)<br>12 (6 kW) | 19.5 (6.4 kW) |
| | Rapid charging (0 to 80%, minutes) | 50 (50 kW) | 40 (90 kW)<br>30 (150 kW) | 37 (90 kW) | 60 (50 kW)<br>40 (90 kW) | 40 (90 kW)<br>30 (150 kW) | 75 (90 kW)<br>60 (150 kW) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date announced/went on sale | | 2022/6/10 | 2022/6/16 | 2022/6/16 | 2022/6/25 | 2022/7/1 | 2022/7/7 |
| Company | | Tesla | Nissan | Mitsubishi | Fiat | BMW | Volvo |
| Name | | Model Y | Nissan Sakura | eK Cross EV | 500 e | i7 | XC40 Recharge |
| Driving wheels | | Rear wheels/all wheels | Front wheels | Front wheels | Front wheels | All | Front wheels/all wheels |
| AC power consumption rate (WLTC, Wh/km) | | — | 124 | 124 | — | 184 | 159 / 188 |
| Cruising range on a single charge (WLTC, km) | | 507 / 595 | 180 | 180 | 335 | 650 | 502 / 484 |
| Motor | Type | AC induction (front)<br>AC synchronous (rear) | AC synchronous | AC synchronous | — | — | AC synchronous (front and rear) |
| | Rated power (kW) | — | 20 | 20 | — | — | 80 / 160 |
| | Maximum power (kW) | — | 47 | 47 | 87 | 190 (front)<br>230 (rear) | 170/150 (front)<br>150 (rear) |
| | Maximum torque (Nm) | — | 195 | 195 | 220 | 365 (front)<br>380 (rear) | 330/330 (front)<br>330 (rear) |
| Battery | Type | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion |
| | Total voltage (V) | — | 350.0 | 350.0 | — | — | 358.0 / 403.0 |
| | Capacity (kWh) | — | 20.0 | 20.0 | 42.0 | 105.7 | 69.0 / 78.0 |
| Charging time | Driving wheels | — | 8 (2.9 kW) | 8 (2.9 kW) | 14 (3 kW)* | 17 (6.4 kW) | 7/8 (9.6 kW)* |
| | Rapid charging (0 to 80%, minutes) | — | 40 (30 kW) | 40 (30 kW) | 40 (50 kW)* | 60 (90 kW)<br>50 (150 kW) | 37 (150 kW) |

**Table 2** Main EVs Launched in Japan in 2022 (Continued)

| Date announced/went on sale | | 2022/7/14 | 2022/9/29 | 2022/9/29 | 2022/10/12 | 2022/11/22 |
|---|---|---|---|---|---|---|
| Company | | Mercedes-Benz | Mercedes-Benz | Mercedes-Benz | Audi | Volkswagen |
| Name | | EQB | EQE Sedan | EQS Sedan | Q4 e-tron/Q4 Sport-back e-tron | ID.4 Lite/ID.4 Pro |
| Driving wheels | | Front wheels/all wheels | Rear wheels/all wheels | Rear wheels/all wheels | Rear wheels | Rear wheels |
| AC power consumption rate (WLTC, Wh/km) | | 147/163 | 176/212 | 182/221 | 145 | 132/139 |
| Cruising range on a single charge (WLTC, km) | | 520/468 | 624/549 | 700/601 | 594 | 435/618 |
| Motor | Type | AC synchronous/ AC induction (front) AC synchronous (rear) | AC synchronous (front and rear) | AC synchronous (front and rear) | — | AC synchronous |
| | Rated power (kW) | — | — | — | 70 | 70 |
| | Maximum power (kW) | 140/143 (front) 72 (rear) | 215/165 (front) 295 (rear) | 245/174 (front) 310 (rear) | 150 | 125/150 |
| | Maximum torque (Nm) | 385 / 370 (F) 150 (R) | 565 / 346 (F) 609 (R) | 568 / 346 (F) 609 (R) | 310 | 310 |
| Battery | Type | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion | Lithium-ion |
| | Total voltage (V) | 362.0 | 328.0 | 396.0 | 352.0 | 352.0 |
| | Capacity (kWh) | 66.5 | 90.6 | 107.8 | 82.0 | 52.0/77.0 |
| Charging time | Normal charging (h) | 11.2 (6 kW) | 16 (6 kW) | 18 (6 kW)* | 25.75 (3 kW) 9.75 (8 kW) | 9/13 (6 kW) |
| | Rapid charging (0 to 80 %, minutes) | 78 (50 kW) 46 (90 kW) | 120 (50 kW) 56 (150 kW) | 126 (50 kW) 55 (150 kW) | 92 (50 kW) | 62 (50 kW) 39 (90 kW) |

*: Calculated from a specifications list.
Note: "—" denotes that there is no publicly available information.

AC charging as well as rapid DC charging up to 250 kW. The Sakura and eK Cross EV are equipped with a motor at the front wheels and mount the traction battery under the floor. Both systems support normal AC charging up to 2.9 kW and rapid DC charging up to 30 kW (CHAdeMO standard). The 500e is equipped with a motor at the front wheels and mounts the traction battery under the floor. The system supports normal AC charging as well as rapid DC charging (CHAdeMO standard).

In July, BMW launched the i7, Volvo launched the XC40 Recharge, and Mercedes-Benz launched the EQB. The i7 is equipped with a motor at both the front and rear wheels that deliver a total maximum power of 400 kW. The traction battery is mounted under the floor and the system supports both normal AC charging and rapid DC charging. Front-wheel-drive versions of the XC40 Recharge have one motor at the front wheels, while four-wheel-drive versions have a motor at both the front and rear wheels that deliver a total maximum power of 300 kW. Both systems support normal AC charging up to 9.6 kW and rapid DC charging up to 150 kW (CHAdeMO standard). Front-wheel-drive versions of the EQB have one motor at the front wheels, while four-wheel-drive versions have a motor at both the front and rear wheels that deliver a total maximum power of 215 kW. The traction battery in these models is mounted under the floor and both systems support normal AC charging up to 6.0 kW as well as rapid DC charging up to 100 kW(CHAdeMO standard).

In September, Mercedes-Benz launched the EQE Sedan and EQS Sedan. Rear-wheel-drive versions of both the EQE Sedan and EQS Sedan have one motor at the rear wheels, while four-wheel-drive versions have a motor at both the front and rear wheels that deliver a total maximum power of 460 kW. The traction battery in these models is mounted under the floor and both systems support normal AC charging up to 6.0 kW as well as rapid DC charging up to 150 kW(CHAdeMO standard).

In October, Audi launched the Q4 e-tron and Q4 Sportback e-tron. Both the Q4 e-tron and Q4 Sportback e-tron are equipped with a motor at the rear wheels and mount the traction battery under the floor. Both systems support normal AC charging up to 8.0 kW and rapid DC charging up to 94 kW (CHAdeMO standard).

In November, Volkswagen launched the ID.4 Lite and ID.4 Pro. Both the ID.4 Lite and ID.4 Pro are equipped with a motor at the rear wheels and mount the traction battery under the floor. The system supports normal AC charging as well as rapid DC charging (CHAdeMO standard).

### 2. 4. Initiatives to Promote EV Popularization

#### (1) National Government Incentives

The Japanese Ministry of Economy, Trade and Industry has introduced subsidies for projects encouraging the adoption of clean energy vehicles as well as a system of Subsidies for Promoting the Introduction of Clean Energy Vehicles and Infrastructure. These subsidies aim to provide support for vehicle purchases, as well for the purchasing and installation costs of charging and discharging infrastructure with the objectives of generating early demand for EVs and other vehicles, reducing vehicle prices, and encouraging the spread of charging infrastructure.

In cooperation with the Ministry of Land, Infrastructure Transport and Tourism (MLIT) and METI, the Ministry of the Environment is also running a project to accelerate the introduction of environmentally friendly advanced trucks and buses. This project aims to support the faster take up of EV trucks and buses in the early phase of adoption by providing subsidies for vehicles and charging infrastructure installation. Another project is working to construct decarbonized logistics systems and the like on a scale that contributes to local communities through the utilization of EVs with replaceable batteries and battery stations. This project is aiming to assist the development and demonstration of EVs with replaceable batteries depending on the application.

In addition, MLIT also continued its project to promote the popularization of next-generation environmentally friendly vehicles to encourage the “greening” of local transportation. In combination with regional policies, the aim of this project is to support the introduction of EVs and other vehicles by providing subsidies to businesses for EVs and the installation of charging infrastructure.

#### (2) Trends for demonstration projects related to EVs

In April 2022, twelve companies including Hokkaido Electric Power Co., Inc. started a car sharing demonstration project using EVs. This project examined the feasibility and issues of a car sharing business using the Nissan Leaf and Tesla Model 3 as test cases. Similarly, three companies including The Chugoku Electric Power Co., Inc. also started a demonstration project involving fully self-reliant EV sharing stations. This project involves operating and verifying EV station systems running entirely on solar power generation. Other aspects of the project include operating and verifying an EV sharing service system with participation from several businesses and local residents, and examining the feasibility of commercializing a solar car port unconnected to the power grid. Three companies including Fabrica Communications Co., Ltd. started field tests of battery state diagnostics technologies for used EVs. These tests are verifying methods of identifying in detail the state and internal condition of batteries, including the remaining capacity and performance, with the aim of ensuring safety, identifying appropriate prices, and establishing evaluation methods for used EVs.

In June, eight companies including MC Retail Energy Co., Ltd. started a demonstration project that adjusts the charging activities of EVs and PHEVs to help realize dynamic pricing. This project is examining how to realize more efficient charging times through the adoption of dynamic pricing. Three companies including The Chugoku Electric Power Co., Inc., Tokushima city and Tokushima Prefecture started field tests with the objective of adopting EVs as official municipal vehicles and achieving efficient operation of charging infrastructure. This project is verifying the impact of these vehicles on reducing $CO_2$ emissions, the usability of charging infrastructure, and the like.

In September, three companies including Mitsubishi Motors Corporation started field tests for realizing efficient operation of mini-vehicle EVs and energy management. This project is using three Minicab-MiEV commercial EVs to collect data related to EV operation and charging and data about the power used by field offices. This data will then be used to identify technical issues affecting the introduction of EVs by companies and business feasibility with the aim of verifying an optimum business model.

## 3 Fuel Cell Electric Vehicles

### 3. 1. Introduction

In the 2000s, the development of fuel cell electric vehicles (FCEVs) centered on passenger vehicles. The focus has shifted in recent years onto heavy-duty commercial vehicles equipped with modularized fuel cells (FCs) Furthermore, the application of modularized FC systems is also expanding to include heavy machinery, trains, marine vessels, stationary generators, and the like, as well as vehicles. This section introduces some of the FCEVs and FC systems announced during 2022, as well as some other FC-related information.

### 3. 2. FCEVs (Heavy-Duty Vehicles) and FC Systems

#### (1) CPJT: light-duty FC truck

As of the time of writing, Isuzu, Toyota, Hino, and Commercial Japan Partnership Technologies (CPJT) announced the acceleration of joint development and market introduction of a mass-market light-duty truck to help achieve carbon neutrality (Fig. 3). Light-duty FC trucks are required to drive long distances over extended hours, while also meeting requirements such as fast refueling capabilities. The use of hydrogen-fueled FC technology is considered effective under such operating conditions. While CJPT is responsible for planning the development of this light-duty FC truck, each company will combine their technological expertise to develop products that satisfy the necessary performance and conditions, with the aim of launching the truck after January 2023.

#### (2) Daimler Buses: Mercedes-Benz eCitaro Range Extender

The Daimler Buses Mercedes-Benz eCitaro Range Extender uses Toyota's second-generation FC module as a generator (Fig. 4). Toyota was in charge of designing and modifying the FC module for installation on a bus. Adopting this FC module extends the range of normal buses to approximately 400 km and articulated buses to a maximum of 350 km.

#### (3) Daimler Truck: Mercedes-Benz GenH2

Daimler Truck started tests of the Mercedes-Benz GenH2 in 2021 (Fig. 5). In 2022, it began tests of liquid hydrogen refueling and driving performance. A truck equipped with two liquid hydrogen tanks with a 40 kg capacity has the same performance as a diesel truck and realized the targeted cruising range of 1,000 km or longer. Daimler Truck is also working with Linde to develop a new process for handling liquid hydrogen (subcooled liquid hydrogen (sLH2) technology). The aim is to realize a higher storage density than conventional liquid hydrogen and simplify the refueling process. The plan is to begin refueling with prototype vehicles in 2023. There are also plans to construct hydrogen infrastructure in partnership with Shell, BP, and TotalEnergies.

#### (4) Iveco: eDaily FCEV

The Iveco Group and Hyundai unveiled the Iveco eDaily heavy-duty FC van at the IAA Transportation commercial vehicle show in Germany in 2022 (Fig. 6). The eDaily FCEV adopts Hyundai's FC system and has a range of 350 km with 12 kg of hydrogen. This truck can also carry up to 3 tons and can be refueled within 15 minutes. Both companies plan to continue cooperating in the future and are considering the joint development of next-generation powertrains, as well as automated driving and connectivity technologies.

#### (5) Ballard Power Systems

Ballard Power Systems has already delivered more than 3,600 FC buses and trucks. It announced FC mod-


**Fig. 3** The CJPT Light-Duty FC Truck (Image)

**Fig. 4** Mercedes-Benz eCitaro Range Extender Equipped with Toyota's Second-Generation FC Module

**Fig. 5** Mercedes-Benz GenH2 Refueling with Liquid Hydrogen


**Fig. 6** Iveco eDaily FCEV Equipped with Hyundai's FC System

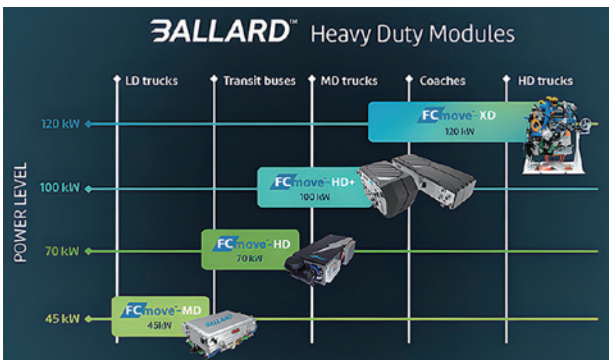


**Fig. 7** Ballard FC System Lineup for Commercial Vehicles

ules for medium- and heavy-duty trucks at the IAA Transportation commercial vehicle show in 2022 (Fig. 7), and plans to adopt its latest FCmove™-XD FC system concept into the Quantron 44-ton truck with a projected release date in the second half of 2023.

**(6) Symbio**

Symbio, an FC system manufacturer from France, announced its HyMotive project to accelerate FC production in October 2022. Under this project, Symbio plans to invest 1 billion euros over seven years with the assistance of the French government. The project aims to create an annual FC system production capacity of 100,000 units by 2028 and 200,000 in 2030 with the objective of becoming a global leader in FC technology.

**(7) Cellcentric**

Cellcentric is a joint venture formed by Daimler Truck and Volvo Trucks in 2021 to manufacture FC systems. At the IAA Transportation commercial vehicle show in 2022, it unveiled a next-generation FC system that delivers power of 150 kW with a weight of 230 kg and a service life of 25,000 hours. The company also announced its intention to displace conventional powertrains by installing two units of this newly developed FC system (total


**Fig. 8** Image of Integrated Powertrain and FC Module Jointly Developed by ZF and Freudenberg

power: 300 kW) into a long-distance truck.

**(8) ZF and Freudenberg**

In September 2022, ZF and Freudenberg announced a tie-up for the joint development of an integrated powertrain and FC module for trucks and buses (Fig. 8). ZF is in charge of developing the electric powertrain and Freudenberg is responsible for the FC system. The initial phase of this joint development will focus on the creation of FC-based e-drive solutions for commercial vehicles. Freudenberg will provide FC systems with various power ratings and ZF will provide an electric drivetrain capable of continuous power output up to 360 kW. Completion of the first prototype is planned for 2023.

### 3. 3. Passenger FCEVs

**(1) American Honda Motor Company**

The American Honda Motor Company is targeting sales of 100% zero-emission electrified vehicles (EVs and FCEVs) in North America by 2040. As part of its efforts to realize this target, the company plans to start production of a new FCEV in Ohio in 2024. This new FCEV was developed based on the CR-V and will feature an additional plug-in function that enables charging at home or from public infrastructure.

**(2) BMW: iX5 Hydrogen**

BMW started production of an SUV-type FCEV called the iX5 Hydrogen in 2022. The FC system is provided by Toyota as a development partner, and generates 275 kW in combination with a traction battery (Fig. 9). With a hydrogen storage capacity of 6 kg, this FCEV has a cruising range of 504 km under the WLTP test cycle.

**(3) NamX: HUV**

NamX is a company of interest aiming to address the issue of insufficient hydrogen infrastructure by introducing an FCEV prototype called the HUV that features the world's first removable cartridge-type hydrogen tank system, an invention that it has successfully patented. In addition to these cartridges, the HUV is also compatible

**Fig. 9** FC System of BMW iX5 Hydrogen

with fixed high-pressure hydrogen tanks and has a predicted cruising range of 800 km. The company plans to start selling the HUV in the fourth quarter of 2025 in a price range between 65,000 and 95,000 euros.

### 3. 4. Regulatory Trends in Japan

The Japanese government has decided to incorporate high-pressure FCEV hydrogen tank regulations into the Road Transport Vehicle Act. Until now, FCEVs have been regulated under both the Road Transport Vehicle Act (under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism) and the High Pressure Gas Safety Act (under the jurisdiction of the Ministry of Economy, Trade and Industry), meaning that users and business operators have to undergo audits under both sets of regulations. However, these audits are to be incorporated under the same scheme from 2023. It is hoped that this change will help to increase the popularization and user-friendliness of FCEVs.

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