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 2020, the number of passenger HEVs on the road in Japan (excluding mini-vehicles) increased by approximately 570,000 from 2019 to reach 9,711,746 vehicles. This is approximately 25% of the total number of passenger vehicles (39,280,408 vehicles) on the road, excluding mini-vehicles. The number of mini HEVs on the road in Japan in 2020 increased by approximately 400,000 vehicles from 2019, and now stands at 1,896,381 vehicles. This is approximately 8% of the total number of mini-vehicles (22,528,178 vehicles) on the road. In addition, the number of passenger PHEVs has also continued to increase since 2009. In 2020, the number of PHEVs on the road increased by approximately 15,000 from 2019 to reach 151,241 vehicles. This is approximately 0.4% of the total number of passenger vehicles on the road, excluding mini-vehicles.

1. 3. New HEVs Launched in Japan in 2021

Table 1 lists the HEVs and PHEVs launched in Japan in 2021 according to the date sales began. The main trends were as follows.

In January, Mercedes-Benz launched the GLC 350 e 4Matic, Audi launched the A5 Sportback 35 TDI, A5 Sportback 45 TFSI Quattro, and A5 Coupé 45 TFSI Quattro, and Peugeot launched the new 3008 GT Hybrid4. The GLC 350 e 4Matic combines a 2-liter inline 4-cylinder turbocharged engine with a plug-in hybrid system. It features a drive battery with a larger capacity than the previous generation and the HEV system outputs 235 kW. The vehicle can drive on motor power alone up to 130 km/h and its cruising range using only external electric power as an energy source (converted EV running distance) is 46.8 km. The A5 Sportback 35 TDI combines a 2-liter inline 4-cylinder direct-injection turbocharged diesel engine with a 12 V mild hybrid system. The A5 Sportback 45 TFSI Quattro and A5 Coupé 45 TFSI Quattro combine a 2-liter inline 4-cylinder direct-injection turbocharged engine with a 12 V mild hybrid system. The new 3008 GT Hybrid4 is Peugeot's first plug-in hybrid four-wheel-drive model. It is equipped with a 1.6-liter inline 4-cylinder turbocharged engine and the e-EAT8 dedicated PHEV transmission. The HEV system outputs 221 kW. The vehicle can drive on motor

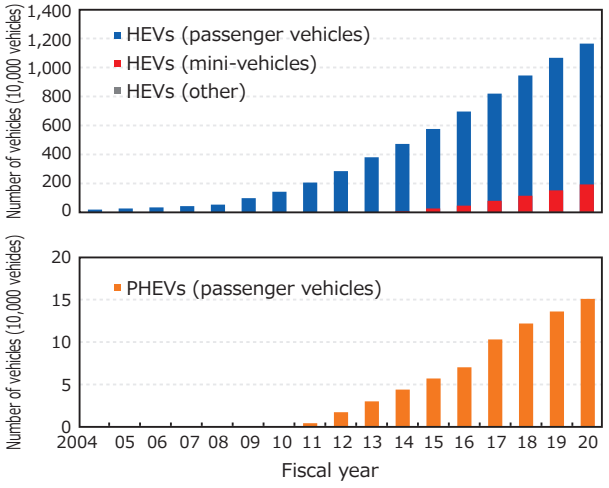

Fig. 1 Trends in the Number of HEVs and PHEVs on the Road in Japan

Table 1 Main HEVs and PHEVs Launched in Japan in 2021

Date announced/went on sale		January 7, 2021	January 13, 2021[*1]	January 27, 2021	February 18, 2021	March 8, 2021
Company		Mercedes-Benz	Audi	Peugeot	Jaguar	Audi
Name		GLC 350 e 4 Matic	A5 35 TDI/ A5 45 TFSI Quattro	New 3008 GT Hybrid4	F-Pace	Q5 40 TDI Quattro/ Q5 45 TFSI Quattro
Type of hybrid system		Parallel	Parallel	Parallel	Parallel	Parallel
Availability of external charging		○	×	○	×	×
Drivetrain		Four-wheel drive	Front-wheel drive / Four-wheel drive	Four-wheel drive	Four-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		12.4	17.1 / 12.9	15.3	14.3	14.5 / 11.6
Engine	使用燃料	Gasoline	Diesel/gasoline	Gasoline	Diesel	Diesel/gasoline
	排気量〔cc〕	1,991	1,968 / 1,984	1,598	1,997	1,968 / 1,984
	最高出力〔kW〕	155	120 / 183	147	150	150 / 183
Motor	種類	AC synchronous motor	—[*]	Front/rear: AC synchronous motor	—	—
	最高出力〔kW〕	90	—	81 (front)/83 (rear)	—	—
Battery	種類	Lithium-ion	—	Lithium-ion	—	—
	Mercedes-Benz	Audi	Peugeot	Jaguar	Audi	—

Date announced/went on sale		March 10, 2021	April 13, 2021	April 23, 2021	May 18, 2021	May 21, 2021
Company		DS Automobiles	McLaren	Honda	Audi	Jaguar
Name		DS 7 Crossback E-Tense 4x4	Artura	Vezel	A3 30 TFSI	E-Pace PHEV Launch Edition
Type of hybrid system		Parallel	Parallel	Series-parallel	Parallel	Parallel
Availability of external charging		○	○	×	×	○
Drivetrain		Four-wheel drive	Rear-wheel drive	Front-wheel drive / Four-wheel drive	Front-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		14.0	—	25.0 /22.0	17.9	—
Engine	使用燃料	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
	排気量〔cc〕	1,598	2,993	1,496	999	—
	最高出力〔kW〕	147	430	78	81	147
Motor	種類	Front/rear: AC synchronous motor	Axial flux motor	AC synchronous motor	—	—
	最高出力〔kW〕	81 (front)/83 (rear)	70	96	—	80
Battery	種類	Lithium-ion	Lithium-ion	Lithium-ion	—	Lithium-ion
	容量〔kWh〕	13.2	7.4	—	—	15.0

Date announced/went on sale		May 26, 2021	June 2, 2021	June 24, 2021	July 19, 2021	July 28, 2021
Company		Mercedes-Benz	Peugeot	Citroën	Toyota	Volkswagen
Name		A 250 e/ A 250 e Sedan	508 GT Hybrid/ 508 SW GT Hybrid	C5 Aircross SUV Plug-In Hybrid	Aqua	Golf Variant
Type of hybrid system		Parallel	Parallel	Parallel	Series-parallel	Parallel
Availability of external charging		○	○	○	×	×
Drivetrain		Front-wheel drive	Front-wheel drive	Front-wheel drive	Front-wheel drive/ Electrical four-wheel drive	Front-wheel drive
Fuel efficiency (WLTC, km/L)		16.3	15.5	16.1	34.6 / 30.0	18.0 / 17.0
Engine	使用燃料	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
	排気量〔cc〕	1,331	1,598	1,598	1,490	999 / 1,497
	最高出力〔kW〕	118	133	133	67	81 / 110
Motor	種類	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor/ AC induction motor (rear)	—
	最高出力〔kW〕	75	81	81	59 (front)/4.7 (rear)	9.4
Battery	種類	Lithium-ion	Lithium-ion	Lithium-ion	Nickel-metal hydride	Lithium-ion
	容量〔kWh〕	15.6	11.8	13.2	—	—

Table 1 Main HEVs and PHEVs Launched in Japan in 2021 (Cont.)

Date announced/went on sale		August 17, 2021	September 10, 2021	September 14, 2021	November 1, 2021	November 1, 2021
Company		Audi	Suzuki	Toyota	Daihatsu	Toyota
Name		Q5 Sportback 40 TDI Quattro	Wagon R Style	Corolla Cross	Rocky	Raize
Type of hybrid system		Parallel	Parallel	Series-parallel	Series	Series
Availability of external charging		×	×	×	×	×
Drivetrain		Four-wheel drive	Front-wheel drive / Four-wheel drive	Front-wheel drive/Electrical four-wheel drive	Front-wheel drive	Front-wheel drive
Fuel efficiency (WLTC, km/L)		14.5	25.1 / 23.6	26.2 / 24.2	28.0	28.0
Engine	使用燃料	Diesel	Gasoline	Gasoline	Gasoline	Gasoline
	排気量〔cc〕	1,968	657	1,797	1,196	1,196
	最高出力〔kW〕	150	36	72	60	60
Motor	種類	—	DC synchronous motor	AC synchronous motor/ AC induction motor (rear)	AC synchronous motor	AC synchronous motor
	最高出力〔kW〕	—	1.9	53 (front)/5.3 (rear)	78	78
Battery	種類	—	Lithium-ion	Lithium-ion/ nickel-metal hydride	Lithium-ion	Lithium-ion
	容量〔kWh〕	—	—	—	—	—

Date announced/went on sale		November 2, 2021	November 24, 2021	December 6, 2021	December 22, 2021
Company		Bentley	Volvo	Maserati	Suzuki
Name		Bentayga Hybrid	XC40 B3	Levante GT	Alto
Type of hybrid system		Parallel	Parallel	Parallel	Parallel
Availability of external charging		○	×	×	×
Drivetrain		Four-wheel drive	Front-wheel drive	Four-wheel drive	Front-wheel drive / Four-wheel drive
Fuel efficiency (WLTC, km/L)		—	14.8	—	27.7 / 25.7
Engine	使用燃料	Gasoline	Gasoline	Gasoline	Gasoline
	排気量〔cc〕	2,994	1,968	1,995	657
	最高出力〔kW〕	250	120	243	36
Motor	種類	—	AC synchronous motor	—	DC synchronous motor
	最高出力〔kW〕	94	10	—	1.9
Battery	種類	Lithium-ion	Lithium-ion	—	Lithium-ion
	容量〔kWh〕	17.3	—	—	—

*: The TDI model was launched in February Note: "—" denotes that there is no publically available information.

power alone up to 135 km/h and its converted EV running distance is 64 km.

In February, Jaguar launched the F-Pace. This model uses mild hybrid technology and is equipped with a 2-liter inline 4-cylinder Ingenium diesel engine.

In March, Audi launched the Q5 40 TDI Quattro and Q5 45 TFSI Quattro, and DS Automobiles launched the DS 7 Crossback E-Tense 4x4. The Q5 40 TDI Quattro is equipped with a 2-liter inline 4-cylinder direct-injection turbocharged diesel engine and the Q5 45 TFSI Quattro is equipped with a 2-liter inline 4-cylinder direct-injection turbocharged engine. Both models feature a mild hybrid system with a belt-driven alternator starter (BAS) and 12 V lithium-ion battery. The DS 7 Crossback E-Tense 4x4 is the first PHEV from DS Automobiles. It combines a 1.6-liter inline 4-cylinder turbocharged engine with a motor installed at both the front and rear wheels. This HEV system outputs 221 kW. The vehicle can drive on motor power alone up to 135 km/h and its converted EV running distance is 56 km.

In April, McLaren launched the Artura and Honda released the Vezel. The Artura features a 3-liter V6 twin turbo engine with plug-in hybrid functionality. The HEV system outputs 500 kW. The vehicle can drive on motor

power alone up to 130 km/h for a maximum of 30 km. The Vezel pairs a 1.5-liter inline 4-cylinder engine with the e-HEV two-motor hybrid system that combines a traction motor with a motor for generating electricity.

In May, Audi launched the A3 Sportback 30 TFSI and A3 Sedan 30 TFSI, Jaguar launched the E-Pace PHEV Launch Edition, and Mercedes-Benz launched the A 250 e and A 250 e Sedan. The A3 Sportback 30 TFSI and A3 Sedan 30 TFSI combine a 1-liter inline 3-cylinder turbocharged engine with a mild hybrid drive system featuring a BAS and a 48 V lithium-ion battery, a first for the premium compact segment in Japan. The E-Pace PHEV Launch Edition is Jaguar's first PHEV to be launched in Japan. It features the P300e PHEV powertrain that combines a 1.5-liter inline 3-cylinder Ingenium engine with an electric rear axle drive system. This HEV system outputs 227 kW. The vehicle can drive on motor power alone for a maximum of 55 km. The A 250 e and A 250 e Sedan combine a 1.4-liter inline 4-cylinder turbocharged engine with a plug-in hybrid system. These vehicles can drive on motor power alone up to 140 km/h with a converted EV running distance of 70.2 km.

In June, Peugeot launched the 508 GT Hybrid and 508 SW GT Hybrid, and Citroén launched the C5 Aircross SUV Plug-In Hybrid. The 508 GT Hybrid and 508 SW GT Hybrid combine a 1.6-liter inline 4-cylinder turbocharged engine with a motor. This HEV system outputs 166 kW (nominal values released by Peugeot's headquarters in France). These vehicles can drive on motor power alone up to 135 km/h with a converted EV running distance of 56 km. The C5 Aircross SUV Plug-In Hybrid is equipped with a plug-in hybrid system that combines a 1.6-liter inline 4-cylinder turbocharged engine with a motor at the front. This HEV system outputs 166 kW (nominal values released by Citroén's headquarters in France). The vehicle can drive on motor power alone up to 135 km/h with a converted EV running distance of 62 km.

In July, Toyota launched the Aqua and Volkswagen launched the Golf Variant. The hybrid system in the Aqua is the THS II with reduction gear. In addition to approximately 20% higher fuel efficiency than the previous model, four-wheel drive (4WD) models are also equipped with the E-Four electrical 4WD system. In addition, the Aqua features the world's first high-power bipolar nickel-metal hydride drive battery. The power of this battery is approximately two times higher than that of the nickel-metal hydride battery of the previous Aqua and expands the speed range in which the vehicle can be driven on motor power alone. All models of this Aqua are equipped as standard with an AC 100 V/1500 W accessory outlet capable of supplying electricity generated by the vehicle after an emergency such as a natural disaster. The Golf Variant is equipped with a mild hybrid system that combines a 48 V belt-driven starter generator with a lithium-ion battery. Two engine types are available: a 1-liter inline 3-cylinder turbocharged engine and a 1.5-liter inline 4-cylinder turbocharged engine. The latter engine is also equipped with an active cylinder management system that raises fuel efficiency by deactivating two out of the four cylinders when the engine load is below a certain level.

In August, Audi launched the Q5 Sportback 40 TDI Quattro. This vehicle combines a 2-liter inline 4-cylinder direct-injection turbocharged diesel engine with a mild hybrid system consisting of a BAS and a 12 V lithium-ion battery.

In September, Suzuki launched the Wagon R Style and Toyota launched the Corolla Cross. The Wagon R Style is equipped with the R06D engine that is extremely fuel-efficient from the low to the middle and high vehicle speed range, which is the practical speed range used by most drivers. This vehicle adopts Suzuki's unique mild hybrid system that combines an integrated starter generator (ISG) with a dedicated lithium-ion battery. The Corolla Cross combines a 1.8-liter inline 4-cylinder engine with the THS II with reduction gear hybrid system. Four-wheel drive models are equipped with the E-Four system.

In November, Daihatsu launched the Rocky, Toyota launched the Raize, Bentley launched the Bentayga Hybrid, and Volvo launched the XC40 B3. The Rocky is equipped with the newly developed e-Smart Hybrid system. This is a series hybrid system that uses the engine to generate electricity, which is then utilized for motor drive. The engine is a newly developed 1.2-liter inline 3-cylinder powerplant designed specifically to generate electricity. Since this vehicle drives on motor power alone, the hybrid system has strong performance at low to medium speeds and is particularly suitable for compact vehicles that are mostly driven in urban areas. The transaxle is a power transmission mechanism consisting of a motor generator for electricity generation and driving, a speed reduction device, and a differential gear. It features two system that are mounted in parallel to re-

duce the length and width of the system. The Raize is also installed with the e-Smart Hybrid system. The Bentayga Hybrid combines a 3-liter V6 turbocharged engine with a motor. This HEV system outputs 330 kW. The vehicle can drive on motor power alone up to 135 km/h for a maximum of 50 km. The XC40 B3 combines a 2-liter inline 4-cylinder direct-injection turbocharged engine with a 48 V mild hybrid system and a newly developed 3-speed dual-clutch transmission (DCT).

In December, Maserati launched the Levante GT and Suzuki launched the Alto. The Levante GT is equipped with a mild hybrid system that combines a 1-liter inline 4-cylinder engine with a 48 V belt-driven starter generator. The Alto is equipped with Suzuki's unique mild hybrid system that combines the R06D engine with an ISG and a dedicated lithium-ion battery.

1. 4. Trends in Standardization

The international standardization of electrified vehicles (including HEVs, battery-driven 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, power consumption, and vehicle charging performance of electrified vehicles, the driving performance and low-temperature startability of FCEVs, and 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 under 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 or power density of the traction battery, or 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, initiatives to expand the popularity of EVs, as well as recent trends in research and development.

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 lithium-ion battery, and the Nissan Leaf in 2010, the number of EVs on the road has steadily increased. At the end of the 2020 fiscal year, there were 130,109 EVs on the road in Japan, approximately 5.2% higher than at the end of fiscal 2019.

2. 3. New EVs Launched in Japan in 2021

Table 2 lists the main EVs launched in Japan in 2021 according to the date sales began. The main trends were as follows.

In January, Audi launched the e-tron 50 Quattro and e-tron Sportback 50 Quattro, and Mazda launched the MX-30 EV Model. The e-tron 50 Quattro and e-tron Sportback 50 Quattro are new grades of the e-tron and e-tron Sportback with a battery capacity adjusted from 95 kWh in the previous grades to 71 kWh. These models feature

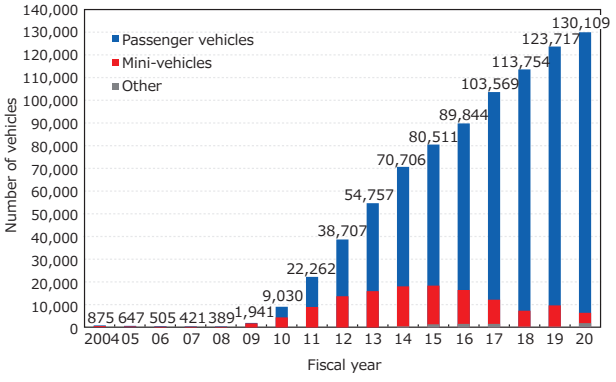

Fig. 2 Change in the Number of EVs on the Road in Japan (as of the End of March each Year)

Table 2 Main EVs Launched in Japan in 2021

Date announced/went on sale		January 13, 2021	January 28, 2021	April 26, 2021	July 29, 2021
Company		Audi	Mazda	Mercedes-Benz	Porsche
Name		e-tron 50 Quattro/ e-tron Sportback 50 Quattro	Mazda MX-30 EV Model	EQA 250	Taycan 4 Cross Turismo
Drivetrain		Four-wheel drive	Front-wheel drive	Front-wheel drive	Four-wheel drive
AC power consumption rate (WLTC, Wh/km)		237 / 223	145	—	—
Cruising range on a single charge (WLTC, km)		316 / 318	256	410	—
Motor	Type	—	AC synchronous motor	AC induction motor	Permanent magnet synchronous motor
	Rated power (kW)	165*1	80.9	—	—
	Maximum power (kW)	230*1	107	140	280*1
	Max. torque (Nm)	540*1	270	370	—
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	—
	Total voltage (V)	397.0	418.0	—	—
	Total power (kWh)	71.0	35.5	66.5	93.4
Charging time	Normal charging (h)	21.33 (3 kW)	12 (3 kW) 5 (6 kW)	11 (6 kW)	9 (11 kW)
	Rapid charging (0 to 80 %, minutes)	61 (50 kW)	40 (40 kW)	—	93 (50 kW)

Date announced/went on sale		November 4, 2021	November 4, 2021	November 4, 2021
Company		BMW	BMW	BMW
Name		iX xDrive40	iX xDrive50	iX3
Drivetrain		Four-wheel drive	Four-wheel drive	Rear-wheel drive
AC power consumption rate (WLTC, Wh/km)		183	190	168
Cruising range on a single charge (WLTC, km)		450	650	508
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor
	Rated power (kW)	65 (F) / 85 (R)	70 (F) / 95 (R)	80
	Maximum power (kW)	190 (F) / 200 (R)	190 (F) / 230 (R)	210
	Max. torque (Nm)	290 (F) / 340 (R)	365 (F) / 400 (R)	400
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion
	Total voltage (V)	330.3	369.0	345
	Total power (kWh)	76.6	111.5	80.0
Charging time	Normal charging (h)	7.25 (11 kW)	10.75 (11 kW)	12.5 (6.4 kW)
	Rapid charging (0 to 80 %, minutes)	42 (150 kW) *2	48 (150 kW) *2	95 (50 kW) *2

*1: System value, *2: *Calculated from specifications list. Note: "—" denotes that there is no publically available information.

a motor at both the front and rear wheels. The Mazda MX-30 EV Model is built on the next-generation SKYACTIV-VEHICLE ARCHITECTURE that was developed specifically for EVs with a stronger frame and body. It adopts the electrified e-SKYACTIV system that coordinates the functions of components such as the motor, brakes, and generator. The system supports normal AC charging up to 6.6 kW and rapid DC charging up to 40 kW (CHAdeMO standard).

In April, Mercedes-Benz launched the EQA, a front-wheel drive vehicle with a motor installed at the front wheels and regenerative braking with five manually adjustable braking force settings. The system supports normal AC charging up to 6.0 kW and rapid DC charging up to 100 kW (CHAdeMO standard).

In July, Porsche launched the Taycan 4 Cross Turismo. This is a 4WD model with one motor installed at both the front and rear wheels that is compatible with both normal AC and rapid DC charging.

In November, BMW launched the iX xDrive40, iX xDrive50, and iX3. The iX xDrive40 and iX xDrive50 are equipped with a motor at both the front and rear wheels,

which deliver a total power of 240 kW for the iX xDrive40 and 385 kW for the iX xDrive50. The system supports normal AC charging up to 11 kW and rapid DC charging up to 150 kW. The iX3 reduces the size and weight of the motor, transmission, and power electronics by integrating these elements into an aluminum housing. It also features regenerative braking with three selectable settings. Its system supports normal AC charging up to 9.6 kW and rapid DC charging up to 80 kW.

In 2021, the main trends for compact electric mobility launched in Japan were as follows.

In March, Honda launched the Gyro e: for corporate customers. The Gyro e: is an electric three-wheeled scooter (class 1 motor-driven cycle (class 1 motorized bicycle)) for business use. It features two Honda Mobile Power Packs (replaceable lithium-ion batteries) and an AC synchronous motor that delivers maximum power of 3.2 kW and maximum torque of 13 Nm.

Then, in October, Honda also launched the Gyro Canopy e for corporate customers and Toyota launched the C^{+}walk T. The Gyro Canopy e: is a class 1 electric three-wheeled scooter with a roof for business use. It features two units of the new higher-capacity Honda Mobile Power Pack e: (replaceable lithium-ion battery) and an AC synchronous motor that delivers maximum power of 3.2 kW and maximum torque of 13 Nm. The C^{+}walk T EV is a three-wheeled standing type version of Toyota's new C^{+}walk mobility series for pedestrianized areas. It features a detachable lithium-ion battery with a total power of 0.27 kW and a brushless DC motor with a maximum power of 0.35 kW.

In December, Toyota made the C^{+}pod available to all customers including individuals, widening the user base from companies and local authorities, which were the original targets when the EV was launched in December 2020.

2. 4. Initiatives to Promote EV Popularization

(1) National Government Incentives

The Japanese Ministry of Economy, Trade and Industry has introduced a system of Subsidies for Promoting the Introduction of Clean Energy Vehicles and Infrastructure. With the aim of popularizing EVs and other clean energy vehicles, this system subsidizes vehicle purchase costs, purchasing and installation costs for the necessary charging infrastructure at highway rest areas, parking areas, housing complexes, businesses, and elsewhere, as well as field operational tests (FOTs) related to the maintenance of systems and the like for electrified vehicle popularization. In addition, subsidies for projects encouraging the adoption of clean energy vehicles that can be used in an emergency have also been introduced as a joint project with the Ministry of the Environment. Under this scheme, individuals are eligible for subsidies contributing to the purchasing costs of EVs and other vehicle, as well as the purchasing and installation costs of charging and discharging infrastructure. The Ministry of the Environment scheme requires applicants to procure 100% renewable energy and participate in monitoring. As well as individuals, this scheme is also open to private businesses (small and medium businesses), local public bodies, and the like.

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 vehicle purchases and charging infrastructure installation.

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 promote the replacement of older models with next-generation vehicles and provides subsidies to businesses for EVs and other vehicles, as well as for the installation of charging infrastructure.

(2) Other Initiatives

In April 2021, with the aim of revitalizing the popularization of EVs and tourism in the city, Aso City in Kumamoto Prefecture started a scheme that awards preferential treatment to EVs, such as free parking and discounts on highway tolls.

In May, Mitsubishi Fuso Truck and Bus signed a collaboration agreement with Atsugi City in Kanagawa Prefecture and ShinMaywa Industries, Ltd. related to the delivery of EV garbage trucks to Atsugi City. Atsugi City planned to introduce and start operating an electric light-duty eCanter garbage truck before the end of the 2021 fiscal year. With the aims of promoting the creation of a recycling-oriented city and a decarbonized society, and achieving carbon neutrality by 2050, the agreement includes details about development and manufacturing related to the introduction of EV garbage trucks, the in-

stallation of charging infrastructure, the provision and utilization of data related to EV garbage truck development, a vehicle service plan, PR for EV garbage trucks, as well as the promotion of global warming countermeasures and innovation toward carbon neutrality. Then, in July, the same company, started downloads of the eTruck Ready App that can simulate the operation of the eCanter. The eTruck Ready App collects real route data from the user's existing diesel trucks and analyzes whether the eCanter can be operated on the same routes. This app is expected to promote awareness of the performance and advantages of EV trucks for users considering their introduction.

2. 5. Trends in Research and Development

In June 2021, five 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 of electricity costs. This project is examining how to adopt more efficient charging times through the adoption of dynamic pricing, in which electricity costs fluctuate in accordance with factors such as the state of power supply and demand.

In November, Idemitsu Kosan, Nissan Motor, and Solar Frontier K.K. started a pilot test project for EV charging services using unique dynamic pricing. Participants in the project are owners of a Nissan Leaf and EV charging infrastructure. The project analyzes changes in participant behavior in response to electricity fee discounts and is verifying the effectiveness and feasibility of this service through surveys. In addition, Yamato Transport Co., Ltd. and Hino have started a field operational test (FOT) of collection and delivery services using Hino's compact and low-bed walk-through Dutro Z EV. This project is validating the reduction effect on greenhouse gas emissions, the efficiency of this truck for collection and delivery services, and other effects such as its capability to reduce workloads. Suzuki is collaborating with Hamamatsu City and the Hamamatsu Shi Flower Fruits Park Kosha Incorporated Foundation in testing the utility of the Kupo electric assistance cart in Hamamatsu Flower Park. Kupo is designed to assist people walking in the park and can also function as a rideable electric wheelchair to support mobility. This is the fourth generation model since the first-generation concept was announced in 2018.

In December. Nissan and the Super City AiCT Consortium announced collaboration in field tests to explore large-scale energy management centered on EVs, methods for utilizing renewable energy, new ways of owning EVs, and the like. In addition to installing solar panels on the Smart City AiCT office building in Aizuwakamatsu in Fukushima Prefecture, this project will test a system consisting of a five Nissan Ariya EVs as renewable energy storage facilities, verify the effectiveness of an energy business using EVs, and examine the compatibility of the system with mobility businesses that utilize these EVs. In addition, this project will use artificial intelligence (AI) to predict EV usage and battery status in the city. By combining these predictions with renewable energy power generation forecasts, the project is aiming to verify the optimization of regional energy utilization. The Organization for Iwaki Battery Valley Promotion and the Murakami Group have announced the start of a joint FOT of an EV-based environmentally friendly mobility service using environmentally friendly power generation technology. This project is obtaining driving data from test vehicles equipped with solar power generation capabilities.

3 Fuel Cell Electric Vehicles

3. 1. Introduction

In the 2000s, the development of fuel cell electric vehicles (FCEVs) was being pursued by a wide range of companies. In 2014, Toyota launched the Mirai, the world's first mass-production FCEV. More recent trends have seen a growing number of fuel cells (FCs) developed for heavy-duty vehicles. The modularization of FC systems has also made progress, and initiatives are under way to widen the application of FCs to trains, marine vessels, stationary generators, and the like, as well as vehicles. This section introduces some of the FCEVs announced during 2021 as well as some other FC-related information.

3. 2. Heavy-Duty FCEVs

Due to the relationship of vehicle weight with cost and driving distance, there is a growing consensus that, for commercial vehicles, EVs are more suited for shorter distances and lighter loads and FCEVs are more suited for longer distances and heavier loads. This section introduces some examples of the heavy-duty FCEVs announced in 2021.

(1) Cellcentric

In March 2021, Daimler Truck and the Volvo Group established a joint venture called Cellcentric to develop

and produce FC systems with the aim of realizing carbon neutrality and sustainable transportation by 2050. This company plans to start mass production of FC trucks by 2030. In addition to FC systems for trucks, Cellcentric is also developing stationary FC systems and is also considering the feasibility of entering other fields.

(2) Hyzon Motors

Hyzon Motors is a start-up in the U.S. that was established in March 2020 to develop and manufacture commercial FCEVs. In March 2021, the company announced that it would build a membrane electrode assembly (MEA) factory for commercial FCEVs. This will be the largest such factory in the U.S. and will have the capacity to produce MEAs for up to 12,000 FC trucks a year. Then, in April 2021, the same company announced the formation of the Hyzon Zero Carbon Alliance as the world's largest consortium working to popularize FC mobility.

3. 3. Passenger FCEVs

(1) Jaguar Land Rover

Jaguar Land Rover announced a FCEV prototype based on the Defender and started tests in 2021. This initiative is part of the company's aim to realize zero tailpipe CO_2 emissions by 2036 and net zero CO_2 emissions across its supply chain, products, and operations by 2039.

(2) Hyvia

Hyvia was established in June 2021 as a joint venture between Renault and Plug Power Inc., and is aiming to launch commercial FCEVs on the market before the end of 2021. The company is planning three types of commercial FCEVs: the Master Van H2-Tech (range: 500 km, cargo capacity: 12 m^3), the Master Chassis Cabine H2-Tech (range: 250 km, cargo capacity: 19 m^3), and the Master City Bus H2-Tech (range: 300 km, passenger capacity: 15).

(3) Stellantis

Stellantis announced that it would start field tests of a compact commercial FCEV in 2021. This model is a plug-in FCEV positioned between a range extender and a full FCEV. It combines the body of a Peugeot Expert with a FC stack that outputs 45 kW supplemented by a 10.5 kWh lithium-ion battery. It carries up to 4.4 kg of hydrogen in three tanks laid out in parallel below the floor and has a cruising range under the Worldwide Harmonized Light Vehicles Test Procedure (WLTP) of 400 km.

(4) BMW

In 2022, BMW started low-volume production of the i Hydrogen Next (Fig. 3), which is equipped with a FC stack (125 kW) jointly developed with Toyota. Its hybrid powertrain outputs 275 kW and the vehicle has a hydrogen storage capacity of 6 kg.

Fig. 3 BMW i Hydrogen Next

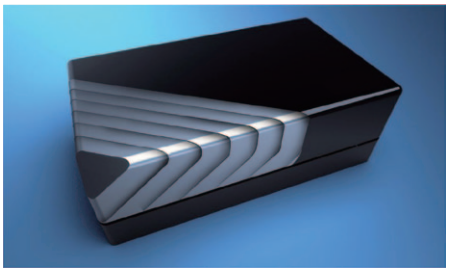

Fig. 4 Toyota Horizontal Type FC Module (Type II)

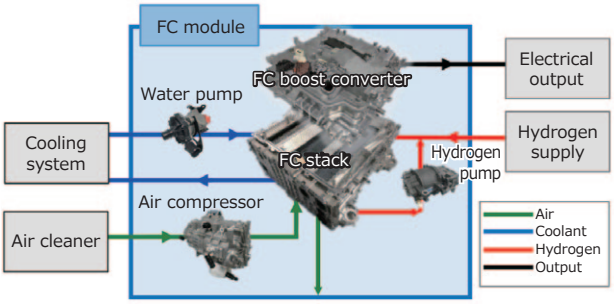

Fig. 5 Example of Connection between Toyota FC Module and External Equipment

3. 4. Non-Automotive Applications of FC Systems

(1) Toyota Motor Corporation

Aiming to accelerate the utilization of hydrogen by popularizing FC products, Toyota started external sales of FC modules (Fig. 4) from the spring of 2021 as an FC systems supplier. These FC modules include an FC stack, control system, hydrogen recirculation pump, air compressor, DC-DC converter, and water pump for cooling. The modules are a simple way to generate power using coolant, hydrogen, and air supplied by the user (Fig. 5). In addition to sales of FC modules, Toyota also provides support for system development to suit the target application of the user.

Fig. 6 Yanmar Maritime FC System Demonstration Test Boat

(2) Yanmar Group

The Yanmar Group has started demonstration tests of a maritime FC system using its own test boat (Fig. 6). The test boat powertrain uses two FC modules developed by Toyota for the Mirai. Yanmar is continuing to work toward the practical application of maritime FC systems. It is aiming to develop a large-capacity package through coordinating the operation of multiple systems and to receive type approval from the ship classification society to enable installation of the system in various vessels in 2023.

3. 5 Relaxation of Regulations

In October 2021, METI released a final report about revising laws and regulations for FCEVs. This report acknowledged that FCEVs are covered by two sets of regulations: the Road Transport Vehicle Act and the High Pressure Gas Safety Act, and described a policy in which types of FCEVs could be exempted from the High Pressure Gas Safety Act if the quality of the hydrogen tanks are verifiable by technical inspections (standard-sized cars, small cars, and light vehicles with three wheels or more).