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 recent trends for HEVs and PHEVs.

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 2019, the number of passenger HEVs on the road in Japan, not including mini-vehicles, increased by around 810,000 vehicles from the previous year to reach approximately 9.14 million vehicles (23% of the total number of passenger vehicles (approximately 39.44 million, excluding mini-vehicles)). The number of passenger PHEVs on the road in Japan has also continued to increase since 2011. In 2019, the number increased by 13,000 from the previous year, reaching approximately 136,000 vehicles. The number of mini HEVs on the road in Japan in 2019 increased by approximately 390,000 vehicles from the previous year, and now stands at approximately 1.49 million vehicles (6.7% of the total number of mini-vehicles (approximately 22.32 million)).

1. 3. New HEVs Launched in Japan in 2020

Table 1 lists the HEVs and PHEVs launched in Japan in 2020 according to the date sales began. The main trends were as follows.

In January, Honda launched the Stepwgn, Mazda launched the CX-30, Flair, and Flair Crossover, and Audi launched the A6 45 TFSI Quattro and A7 Sportback 45 TFSI Quattro. The Stepwgn is equipped with the highly efficient e-HEV two-motor hybrid system that combines a traction motor with a motor for generating electricity. The traction motor is provided on the driveshaft and the generator is directly connected to the engine to minimize friction loss. The CX-30 is equipped with the M-HYBRID mild hybrid system that combines a 24 V lithium ion battery and a belt-driven integrated starter generator (ISG) as an alternating current (AC) synchronous motor. The Flair and Flair Crossover are equipped with a mild hybrid system, which features an ISG as a direct current motor that generates electricity using the energy created when the vehicle slows down (this electricity charges the lead-acid battery in models equipped with a start-stop system as well as the dedicated lithium ion battery), and which assists the engine when the vehicle accelerates. The A6 45 TFSI Quattro and A7 Sportback 45 TFSI Quattro are equipped with a mild hybrid system that features a belt-driven alternator starter (BAS) and a 12 V battery.

In February, Honda launched the Fit and Accord. Both these models are equipped with the same e:HEV hybrid system adopted on the Stepwgn launched in January.

In March, Mitsubishi launched the eK Space and eK

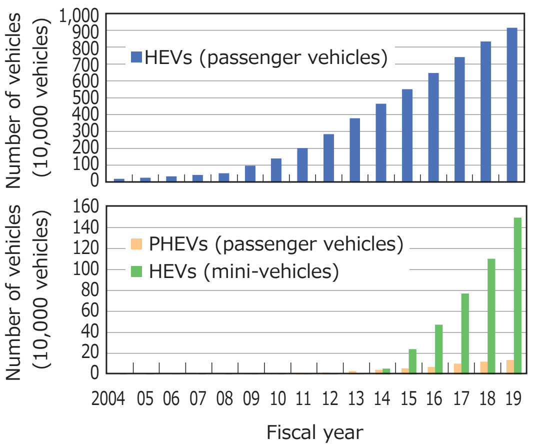

Fig. 1 Trends in the Number of HEVs and PHEVs on the Road in Japan

Table 1 Main HEVs and PHEVs Launched in Japan in 2020

Date announced/went on sale		January 9, 2020	January 16, 2020	January 22, 2020	January 23, 2020	January 29, 2020
Company		Honda	Mazda	Audi	Mazda	Mazda
Name		Stepwgn	CX-30	A6 45 TFSI Quattro/A7 Sportback 45 TFSI Quattro	Flair	Flair Crossover
Type of hybrid system		Series-parallel (HEV)	Parallel (HEV)	Parallel (HEV)	Parallel (HEV)	Parallel (HEV)
Drivetrain		Front-wheel drive	Front-wheel drive/ four-wheel drive	Four-wheel drive	Front-wheel drive/ four-wheel drive	Front-wheel drive/ four-wheel drive
Fuel efficiency (WLTC, km/L)		20.0	16.8	11.4	25.2	25.0 / 22.6
Engines	Designation	LFA-H4	HF-VPH	DKN	R06 D	R06 D/R06 A
	Displacement (cc)	1,993	1,997	1,984	657	657 / 658
	Maximum power (kW)	107	140	180	36	36 /47
Motor	Type	AC synchronous motor	AC synchronous motor	—	DC synchronous motor	DC synchronous motor
	Maximum power (kW)	135	4.8	—	1.9	1.9 / 2.3
Battery	Type	Lithium-ion	Lithium-ion	—	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	—	—	—	—

Date announced/went on sale		February 13, 2020	February 20, 2020	March 19, 2020	March 23, 2020	April 2, 2020
Company		Honda	Honda	Mitsubishi	Mercedes-Benz	Audi
Name		Fit	Accord	eK Space/eK Cross Space	GLS 580 4 MATIC	A6 40 TDI Quattro/ A7 Sportback 40 TDI Quattro
Type of hybrid system		Series-parallel (HEV)	Series-parallel (HEV)	Parallel (HEV)	Parallel (HEV)	Parallel (HEV)
Drivetrain		Front-wheel drive/ four-wheel drive	Front-wheel drive	Front-wheel drive/ four-wheel drive	Four-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		29.4	22.8	20.8	8.3	16.1
Engines	Designation	LEB-H5	LFB-H4	BR06	M176	DFB
	Displacement (cc)	1,496	1,993	659	3,982	1,968
	Maximum power (kW)	72	107	38	360	150
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	—
	Maximum power (kW)	80	135	2	10	—
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	—	—	—	—

Date announced/went on sale		April 3, 2020	April 9, 2020	April 23, 2020	June 8, 2020	June 11, 2020
Company		Mercedes-Benz	BMW	Volvo	Toyota	Mercedes-Benz
Name		GLC 350 e 4 MATIC	X3 xDrive30 e	XC60 B5 /XC90 B5	RAV4 PHV	GLE 53 4 MATIC+
Type of hybrid system		Series-parallel (PHEV)	Series-parallel (PHEV)	Parallel (HEV)	Series-parallel (PHEV)	Parallel (HEV)
Drivetrain		Four-wheel drive	Four-wheel drive	Four-wheel drive	Four-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		12.3	11.8	11.5 / 10.9	22.2	9.7
Engines	Designation	M274	B48 B20 A	B420 T2	A25 A-FXS	M256
	Displacement (cc)	1,991	1,998	1,968	2,487	2,996
	Maximum power (kW)	155	135	184	130	320
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor	Front/rear: AC synchronous motor	AC synchronous motor
	Maximum power (kW)	60	80	8	134 / 40	10
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	12	—	18.1	—

Table 1 Main HEVs and PHEVs Launched in Japan in 2020 (Cont.)

Date announced/went on sale		June 17, 2020	June 19, 2020	June 30, 2020	August 6, 2020	August 18, 2020
Company		Toyota	Honda	Nissan	Lexus	Audi
Name		Harrier	CR-V	Kicks e-Power	ES300 h	Q7
Type of hybrid system		Series-parallel (HEV)	Series-parallel (HEV)	Series (HEV)	Series-parallel (HEV)	Parallel (HEV)
Drivetrain		Front-wheel drive/ four-wheel drive	Front-wheel drive/ four-wheel drive	Front-wheel drive	Front-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		22.3	25.8	21.6	22.3	9.3
Engines	Designation	A25 A-FXS	LFB-H4	HR12 DE	A25 A-FXS	DCB
	Displacement (cc)	2,487	1,993	1,198	2,487	2,994
	Maximum power (kW)	131	107	60	131	250
Motor	Type	Front/rear: AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	—
	Maximum power (kW)	88 / 40	135	95	88	—
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	—
	Capacity (kWh)	—	—	—	—	—

Date announced/went on sale		August 25, 2020	August 25, 2020	August 25, 2020	August 25, 2020	August 25, 2020
Company		Audi	Audi	Volvo	Volvo	Volvo
Name		S8	S6 /S6 Avant/S7 Sportback	XC40 Recharge Plug-in Hybrid T5 Inscription	XC40 B4 /XC40 B5	XC60 B6 /XC90 B6
Type of hybrid system		Parallel (HEV)	Parallel (HEV)	Series-parallel (PHEV)	Parallel (HEV)	Parallel (HEV)
Drivetrain		Four-wheel drive	Four-wheel drive	Front-wheel drive	Front-wheel drive/ four-wheel drive	Four-wheel drive
Fuel efficiency (WLTC, km/L)		7.8	9.5	14.0	12.7 / 12.8	11.1 / 10.5
Engines	Designation	CWW	DKM	B3154	B420 T6 /B420 T2	B420 T
	Displacement (cc)	3,996	2,893	1,476	1,968	1,968
	Maximum power (kW)	420	331	132	145 / 184	220
Motor	Type	—	—	AC synchronous motor	AC synchronous motor	AC synchronous motor
	Maximum power (kW)	—	—	30	8	8
Battery	Type	—	—	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	—	—	—	—

Date announced/went on sale		August 31, 2020	September 4, 2020	September 28, 2020	October 5, 2020	October 7, 2020
Company		Toyota	Subaru	BMW	Mercedes-Benz	Audi
Name		Yaris Cross	XV	530 e	E 200/E 450 4 MATIC	A4 /A4 Avant
Type of hybrid system		Series-parallel (HEV)	Parallel (HEV)	Series-parallel (PHEV)	Parallel (HEV)	Parallel (HEV)
Drivetrain		Front-wheel drive/ four-wheel drive	Four-wheel drive	Rear-wheel drive	Rear-wheel drive/ four-wheel drive	Front-wheel drive/ four-wheel drive
Fuel efficiency (WLTC, km/L)		30.8	19.2	12.8	13.1 /11.1	13.6 /12.9
Engines	Designation	M15 A-FXE	FB20	B48 B20 A	M264 /M256	DEM/DDW
	Displacement (cc)	1,490	1,995	1,998	1,496 / 2,966	1,984
	Maximum power (kW)	67	107	135	135 / 270	110 / 183
Motor	Type	AC synchronous motor/ AC induction motor	AC synchronous motor	—	AC synchronous motor	—
	Maximum power (kW)	59 / 3.9	10	—	8 / 10	—
Battery	Type	Lithium-ion	Lithium-ion	—	Lithium-ion	—
	Capacity (kWh)	—	—	—	—	—

Table 1 Main HEVs and PHEVs Launched in Japan in 2020 (Cont.)

Date announced/went on sale		October 8, 2020	October 8, 2020	October 21, 2020	October 21, 2020	October 21, 2020
Company		Subaru	Mazda	Jeep	Volvo	Volvo
Name		Impreza	MX-30	Renegade 4 xe	V90 B5 /V90 B6	V60 B4 /V60 B5
Type of hybrid system		Parallel (HEV)	Parallel (HEV)	Series-parallel (PHEV)	Parallel (HEV)	Parallel (HEV)
Drivetrain		Four-wheel drive	Front-wheel drive/ four-wheel drive	Four-wheel drive	Four-wheel drive	Front-wheel drive
Fuel efficiency (WLTC, km/L)		5.4	15.6	17.3	10.9 / 10.5	12.8
Engines	Designation	FB20	PE-VPH	46337540	B420 T2 /B420 T	B420 T6 /B420 T2
	Displacement (cc)	1,995	1,997	1,331	1,968	1,968
	Maximum power (kW)	107	115	96	184 /220	145 / 184
Motor	Type	AC synchronous motor	AC synchronous motor	Front/rear: AC synchronous motor	AC synchronous motor	AC synchronous motor
	Maximum power (kW)	10	5.1	14.5 / 44.0	8	8
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	—	11.4	—	—

Date announced/went on sale		November 26, 2020	December 4, 2020	December 4, 2020	December 15, 2020	December 23, 2020	December 24, 2020
Company		Volvo	Mitsubishi	Suzuki	Mercedes-Benz	Nissan	Mitsubishi
Name		S60 B4 /S60 B5	Eclipse Cross	Solio/Solio Bandit	GLE 63	Note e-Power	Delica D:2
Type of hybrid system		Parallel (HEV)	Series-parallel (PHEV)	Parallel (HEV)	Parallel (HEV)	Series (HEV)	Parallel (HEV)
Drivetrain		Front-wheel drive	Four-wheel drive	Front-wheel drive/ four-wheel drive	Four-wheel drive	Front-wheel drive	Front-wheel drive/ four-wheel drive
Fuel efficiency (WLTC, km/L)		12.8 / 14.3	16.4	19.6	7.7	29.5	19.6
Engines	Designation	B420T6 / B420T2	4B12 MIVEC	K12C	M177	HR12DE	K12C
	Displacement (cc)	1,968	2,359	1,242	3,982	1,198	1,242
	Maximum power (kW)	145 / 184	94	67	450	60	67
Motor	Type	AC synchronous motor	Front/rear: AC synchronous motor	DC synchronous motor	AC synchronous motor	AC synchronous motor	DC synchronous motor
	Maximum power (kW)	8	60 / 70	2.3	10	85	2.3
Battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	—	13.8	—	—	—	—

Note: "-" denotes that the horsepower figure has not been publically released.

Cross Space, and Mercedes-Benz launched the GLS 580 4MATIC. The eK Space and eK Cross Space are equipped with a hybrid system that uses a motor to assist the engine during acceleration. The GLS 580 4MATIC is equipped with a hybrid system that combines a 48 V battery and an ISG.

In April, Audi launched the A6 40 TDI Quattro and A7 Sportback 40 TDI Quattro, Mercedes-Benz launched the GLC 350 e 4MATIC, BMW launched the X3 xDrive30e, and Volvo launched the XC60 B5 and XC90 B5. The A6 40 TDI Quattro and A7 Sportback 40 TDI Quattro are equipped with 12 V mild hybrid system that combines a larger BAS than a normal starter motor, a lithium ion battery, and a conventional battery for the electrical system. This system disengages the engine when coasting between 55 and 160 km/h, acts as a start-stop system at 22 km/h or less, and can provide assistance to the engine for 5-second periods. The GLC 350 e 4MATIC is equipped with a plug-in hybrid system. Its cruising range using only external electric power as an energy source (converted EV running distance) is 45.2 km. In addition, the maximum power of the hybrid system is 235 kW, and the vehicle can drive on motor power alone up to 130 km/h. The X3 xDrive30e is the first member of the X3 lineup to be equipped with a plug-in hybrid system. Its converted EV driving distance is 44 km. In addition, the maximum power of the hybrid system is 215 kW, and the vehicle can drive on motor power alone up to 140 km/h. The XC60 B5 and XC90 B5 are equipped with a hybrid system featuring an integrated starter generator module (ISGM) that charges a 48 V lithium ion battery using power generated during regenerative braking. This system also assists the engine at start-up and provides other dynamic assistance.

In June, Toyota launched the RAV4 PHV and Harrier, Mercedes-Benz launched the GLE 53 4MATIC+, Honda launched the CR-V, and Nissan launched the Kicks e-Power. The RAV4 PHV is equipped with a newly developed plug-in hybrid system called the THS II Plug-in and achieves a converted EV driving distance of 95 km. The hybrid system in the Harrier is the THS II with reduction gear. The GLE 53 4MATIC+ is equipped with a hybrid system that combines an inline 6-cylinder engine, ISG, 28 V lithium ion battery, and electric supercharger. The CR-V uses the e:HEV hybrid system. The Kicks e-Power is equipped with the e-Power electric powertrain (a series hybrid system that uses the engine only to generate electricity).

In August, Lexus launched the ES300h, Audi launched the Q7, S8, S6, S6 Avant, and S7 Sportback, Volvo launched the XC40 Recharge Plug-in Hybrid T5 Inscription, XC40 B4, XC40 B5, XC60 B6, and XC90 B6, and Toyota launched the Yaris Cross. The ES300h is equipped with the Lexus Hybrid Drive system, which increases the fuel efficiency of the vehicle by 1.7 km/L compared to the previous model by adopting a lithium ion battery instead of a nickel-metal hydride battery. The Q7, S8, S6, S6 Avant, and S7 Sportback are equipped with the MHEV mild hybrid drive system that combines a BAS with a 48 V lithium ion battery. The XC40 Recharge Plug-in Hybrid T5 Inscription is the first model built on the Compact Modular Architecture (CMA: a platform designed for compact vehicles) to be equipped with a plug-in hybrid system. Its converted EV driving distance is 45.6 km. The XC40 B4 and XC40 B5 are equipped with hybrid systems (the B4 and B5 systems) featuring an ISGM that charges a 48 V lithium ion battery using power generated during regenerative braking. This system also assists the engine at start-up and provides other dynamic assistance. The XC60 B6 and XC90 B6 supplement the hybrid system from the XC60 and XC90 B5 with an electric supercharger to realize both high power and high efficiency. The hybrid system in the Yaris Cross is the THS II with reduction gear. The four-wheel drive model is equipped with the E-Four electrical four-wheel drive system, which is provided with a separate motor for driving the rear wheels.

In September, Subaru launched the XV and BMW launched the 530e. The XV is equipped with the e-Boxer power unit that combines a motor with a horizontally opposed engine. e-Boxer models feature the SI-Drive control system, which activates when the system determines that the vehicle is being driven sportily based on whether the vehicle has entered a corner and the accelerator and brake pedal operation status. The system supports cornering performance by maintaining high engine speeds, and realizes powerful acceleration after the corner through motor assist. The 530e is equipped with a plug-in hybrid system that achieves a converted EV driving distance of 54 km.

In October, Mercedes-Benz launched the E 200 and E 450 4MATIC, Audi launched the A4 and A4 Avant, Subaru launched the Impreza, Mazda launched the MX-30, Jeep launched the Renegade 4xe, and Volvo launched the V90 B5, V90 B6, V60 B4, and V60 B5. The E 200 and E 450 4MATIC are equipped with a hybrid system that combines a BSG (E 200) or ISG (E 450 4MATIC) and a 48 V lithium ion battery. This system charges the lithium ion battery using power generated during regenerative braking and the like, and provides assistance of up to 160 Nm of torque when required to realize low-vibration engine starts, acceleration, gear shifting, and so on. The A4 and A4 Avant are equipped with the MHEV mild hybrid drive system that features a BAS and a 12 V lithium ion battery. The Impreza is equipped with the same e-Boxer power unit as the XV, and the MX-30 uses the M-Hybrid system. The model of the Renegade 4xe imported to Japan is equipped with a plug-in hybrid system for the first time. Its converted EV driving distance is 48 km. The V90 B5, V90 B6, V60 B4, and V60 B5 are equipped with the B5, B6, B4, and B5 hybrid systems, respectively.

In November, Volvo launched the S60 B4 and S60 B5. The hybrid system in these models features an ISGM that charges a 48 V lithium ion battery.

In December, Mitsubishi launched the Eclipse Cross and Delica D:2, Suzuki launched the Solio and Solio Bandit, Mercedes-Benz launched the GLE 63, and Nissan launched the Note e-Power. The Eclipse Cross uses the same two-motor four-wheel drive plug-in hybrid system as the Outlander PHEV, and achieves a converted EV driving distance of 57.3 km. The Delica D:2 is equipped with a hybrid system that combines an ISG and a lithium ion battery. The Solio and Solio Bandit also adopt a hybrid system that combines an ISG and a lithium ion battery. The GLE 63 is the first model in the 63 lineup to feature a hybrid system, which in this case combines an ISG with a 48 V lithium ion battery. The output of the motor adopted by the Note e-Power is 6% higher than the motor used by the previous generation. The size and weight of the inverter were reduced by 40% and 30%, respectively, resulting in higher fuel efficiency.

1. 4. Trends in HEV Standardization

The international standardization of electrified vehicles including HEVs, battery electric vehicles (BEVs), 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 (including non-contact energy transfer) and the performance and safety aspects of secondary batteries. Up until 2019, Japan led standardization efforts related to reliability and performance test methods for motor systems and DC-DC converters. The results of these efforts were published in 2020 as international standards. In addition, based on hardware in the loop simulations (HILS) that have been defined as test methods for the fuel efficiency and emissions of heavy-duty HEVs, studies are under way aiming to incorporate technologies from Japan into international standards for vehicles other than heavy-duty HEVs. Examples include methods for measuring the fuel efficiency of FCEVs equipped with an external charging function, methods for measuring the fuel efficiency of heavy-duty FCEVs, and methods for measuring the cruising range of BEVs and FCEVs.

2 Electric Vehicles

2. 1. Introduction

Electric vehicles (EVs) are powered entirely by motors using electricity supplied externally and charged to an on-board battery, rather than power from an ICE or fuel cell. These vehicles are often referred to as battery electric vehicles (BEVs) or pure electric vehicles (PEVs). This section uses the general abbreviation EV. EVs are attracting attention as extremely quiet environmentally friendly vehicles that emit no harmful tailpipe emissions. Starting in 2009 with the launch of the i-MiEV by Mitsubishi (this was the world's first mass-produced EV equipped with a high capacity lithium-ion battery (LIB) and was mainly sold to corporate customers), the number of EVs on the road in Japan has steadily increased, reaching in excess of around 120,000 by the end of fiscal 2019, approximately 9% higher than at the end of fiscal 2018.

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, as well as the recent trends in research, development, and standardization.

2. 2. Extent of EV Use and Efforts to Increase Popularization in Japan

(1) Popularization and Sales 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 i-MiEV by Mitsubishi in 2009 and the Leaf by Nissan in 2010, the number of EVs on the road has steadily increased, reaching 123,717 vehicles at the end of 2019.

Table 2 lists the main EVs (passenger vehicles) launched in Japan in 2020 according to the date sales began. The main trends were as follows.

In July, Peugeot launched the e-208 for Japan. It uses a highly efficient motor with maximum power of 100 kW and maximum torque of 260 Nm. The characteristics of

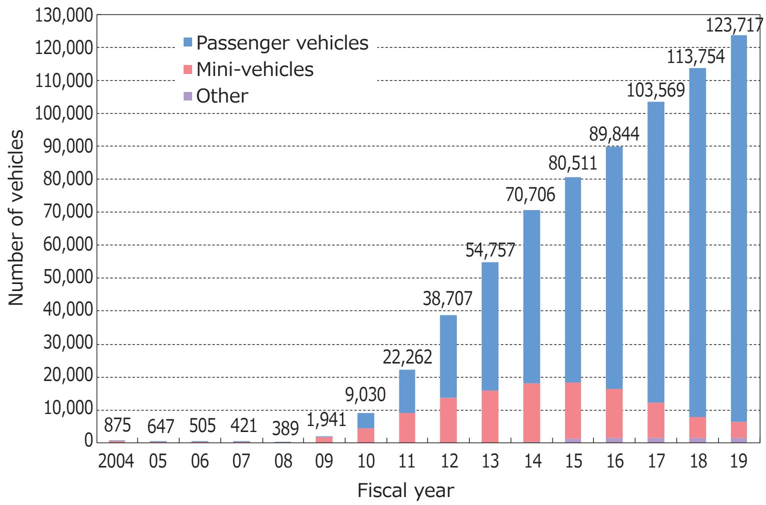

Fig. 2 Change in the Number of EVs on the Road in Japan (as of the End of March each Year)

this motor that generate maximum torque when the vehicle moves off ensure agile and smooth acceleration. The e-208 also uses a newly developed platform that allows the installation of a high-capacity 50 kWh LIB with the same amount of cabin and luggage compartment space as the ICE model in the same lineup. Its range per charge is 403 km (JC08 test cycle).

In September, Audi launched the Audi e-tron Sportback as its first EV for the Japanese market. Equipped with two motors, one each at the front and rear, the e-tron Sportback achieves a maximum power of 300 kW and 0 to 100 km/h acceleration of 5.7 seconds (when boosted in S Mode, or 6.6 seconds in the normal D shift position). The e-tron Sportback has a battery capacity of 95 kWh and a range per charge of 405 km (WLTC).

In October, Honda launched the Honda e with a battery capacity of 35.5 kWh and a range per charge of 283 km (WLTC).

In December, Toyota launched the C$^+$pod for corporate users, local authorities, and similar. In addition to short-distance daily use, the C$^+$pod was specifically developed for corporate users visiting customers on a regular basis, and users in urban or mountainous communities. The battery capacity of the C$^+$pod is 9.06 kWh and it has a range per charge of 150 km (WLTC).

(2) Initiatives to Promote EV Popularization

In March 2020, Nissan launched a project to add zero emission vehicles (ZEVs) to rental car and car sharing fleets in Tokyo in the 2019 fiscal year. Nissan also announced that it had added 45 EVs to the Nissan e-Share Mobi car sharing service. Services using these EVs are being offered at lower than usual prices to increase the opportunities of Tokyo residents to drive ZEVs.

In June, Nissan opened Nissan e-Share Mobi EV stations inside the Kanazawa Institute of Technology. These are the first such stations to be opened inside a university in Japan. Nissan is aiming to raise environmental awareness and promote the usage of EVs by giving more people the opportunity to experience the quietness and environmental performance of an EV.

In July, as part of efforts to popularize renewable energy generated by EVs, two Nissan dealers in Ibaraki Prefecture teamed up with the Smart Tech company to start offering customers purchasing a new Nissan Leaf free installation of solar power generation systems and a plan that provides access to cheaper electricity during daytime hours. The same company is accelerating its efforts to popularize renewable energy generated by EVs across the whole country.

In October, it announced support for the Sanriku Fireworks Competition using power generated by EVs. Specifically, it is supplying power from EVs to power video, audio, and other electrical equipment at the venue to promote the popularization of EVs by actively demonstrating the effectiveness and applicability of EVs as driveable batteries to ordinary people.

In the 2020 fiscal year, following on from its efforts in the 2019 fiscal year, the Japanese Ministry of Economy, Trade and Industry (METI) is offering subsidies to promote the adoption of clean-energy vehicles (CEV subsidies). In addition to the vehicles covered in the 2019 fis-

Table 2 Main EVs Launched in Japan in 2020

Launch date		July 2, 2020	September 17, 2020	October 30, 2020	December 25, 2020
Manufacturer		Peugeot	Audi	Honda	Toyota
Name		e-208	Audi e-tron Sportback	Honda e	C+pod*2
Length × width × height (mm)		4,095 × 1,745 × 1,465	4,900 × 1,935 × 1,615	3,895 × 1,750 × 1,510	2,490 × 1,290 × 1,550
Occupant capacity		5	5	4	2
AC power consumption rate (WLTC, Wh/km)		131 (JC 08 test cycle)	245	131	54
Cruising range on a single charge (WLTC, km)		403 (JC 08 test cycle)	405	283	150
Traction battery	Type	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Total voltage (V)	395	397	355.2	177.6
	Total power (kWh)	50	95	35.52*1	9.06
Motor	Rated output (kW)	57	165	60	2.6
	Maximum power (kW)	100	300	100	9.2
	Max. torque (Nm)	260	664	315	56
Charging time	Normal charging (3 kW) (h)	18	32*1	12	5
	Rapid charging (0 to 80%, minutes)	50	83*1	30	—

*1 : Calculated from a specifications list or the like
*2 : Fleet sales only This is an ultra-compact mobility vehicle (type designated) with a top speed of 60 km/h. It cannot be driven on expressways.

cal year, the subsidies were expanded to cover vehicles without a power supply function. METI is also offering subsidies to promote the development of EV and PHEV charging infrastructure. With the aim of popularizing EVs and other clean energy vehicles, these projects are subsidizing the purchase cost of EVs and other vehicles, as well as the purchase and engineering costs for charging infrastructure in housing complexes, businesses, parking spaces in service and parking areas on expressways, and elsewhere.

Also in the 2020 fiscal year, again following on from its efforts in the 2019 fiscal year, the Japanese Ministry of Land, Infrastructure Transport and Tourism (MLIT) continued its project to promote the popularization of next-generation environmentally friendly vehicles to encourage the “greening” of local transportation. The aim of this project is to promote the popularization of next-generation environmentally friendly vehicles through the concentrated introduction of next-generation vehicles and the purchase of these vehicles to replace older models. The project offers subsidies for EV buses and other vehicles, as well as for introducing charging facilities for EVs and other related items.

2. 3. Trends in EV Research and Development

(1) Vehicle Development

In February 2020, Toyota and Panasonic Corporation decided to establish a joint venture called Prime Planet Energy & Solutions, Inc. It started operations in April, including the development of extremely safe, high-quality, high-performance (in terms of capacity, power, durability, and the like), and low-cost batteries. This joint venture is aiming to realize stable battery supplies for a wide range of companies as well as Toyota.

In April, BYD Co. Ltd. and Toyota completed the registration of a joint venture called BYD Toyota EV Technology Co., Ltd., with the aim of starting operations in May. This joint venture aims to take advantage of the strengths of both BYD and Toyota to design and develop EVs, EV platforms, and related parts to help improve the environment in China.

In April 2020, Nissan announced that it had licensed its advanced bipolar structure all-polymer battery technology for LIBs to APB Corporation. APB is aiming to use this technology to commercialize next-generation stationary all-polymer LIBs, and is also planning to build a factory in Japan capable of producing batteries with a total annual charging capacity in the GWh class.

In May 2020, Nissan also announced that Japan’s first EV ambulance had entered service with the Tokyo Fire Department. This ambulance is equipped with electric stretchers to help alleviate the workload of the paramedics. In addition, since an ambulance is required to relieve the physical strain on both patients and crew, and must also carry high-precision medical equipment, the quietness and low vibration of an EV is thought to be particularly applicable. This ambulance is equipped with two LIBs (33 kWh and 8 kWh) capable of operating the on-board electrical equipment and air conditioning for extended periods of time. These batteries can also be used as mobile power supplies during blackouts and after a natural disaster.

In December 2020, Toyota demonstrated the operations management system of the e-Palette. This operations management system will be provided as new functions on Toyota's Mobility Services Platform (MSPF, an open platform that provides various functions necessary for mobility services to mobility service providers via an API), and consists of the Autonomous Mobility Management System (AMMS, a system that dispatches the required number of e-Palettes to the required locations at the required times) and the e-Palette Task Assignment Platform (e-TAP, to support staff involved in the running of the services and to visualize errors). The system aims to help reduce customer waiting times and alleviate congestion, thereby enabling services that provide safety, peace of mind, and comfort.

(2) Demonstration Projects

In August 2020, Toyota and Honda announced the start of demonstration testing of a mobile power generation and output system called Moving e, which is capable of delivering electricity anytime and anywhere. Moving e consists of Toyota's CHARGING STATION fuel cell bus, Honda's Power Exporter 9000 portable external power output device, two portable batteries (the LiB-AID E500 and Honda Mobile Power Pack (MPP)), and the Honda Mobile Power Pack Charge & Supply Concept charger/discharger for the MPP. With the fuel cell bus acting as the power source, electricity is supplied from the bus using the portable external power output device and portable batteries to power electrical equipment. Through this demonstration testing, the two companies will verify the effectiveness of Moving e as a phase-free system ("phase-free" refers to the concept of utilizing the same products and services in both normal times and also in times of an emergency).

In October 2020, Nissan announced the start of a demonstration project aiming to shift the charging of electrified vehicles by dynamic pricing. Aimed at Nissan Leaf owners in Fukuoka and Nagasaki Prefectures, the project will analyze and verify the effects of variable time-based electricity fees on the charging behavior of EV owners.

2. 4. Trends in Standardization

The standardization of EVs is carried out by the ISO and the International Electrotechnical Commission (IEC).

International standards for overall vehicles, electric drive systems, and parts are being created under the auspices of ISO/TC 22/SC 37. (Refer to Section 1.4. Trends in HEV Standardization for details.)

3 Fuel Cell Electric Vehicles

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 due to the cost advantages of FCs over EVs. Studies into the modularization of FC systems have also made progress, and plans have been announced to widen the application of FCs to trains, marine vessels, stationary generators, and the like, as well as vehicles.

3. 1. Global Plans to Build Hydrogen Refueling Stations

Figure 3 shows the number of hydrogen refueling stations opened in various countries and future building plans as an index of measures to promote FCEVs around the world. All the countries shown in the graph are planning to build more refueling stations exponentially by 2030. In Japan, 137 hydrogen refueling stations are in business, primarily in the Tokyo metropolitan, Chukyo, Kansai, and northern Kyushu areas (as of December 2020, locations supported by a government project to stimulate new demand for FCEVs). It is planned to continue building hydrogen refueling stations centered on main routes between these locations.

3. 2. Trends in FCEV Development (Passenger Vehicles)

This section describes the second-generation Toyota

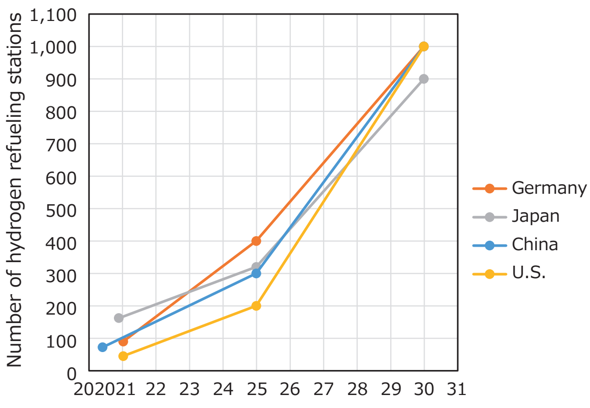

Fig. 3 Number of Hydrogen Refueling Stations Opened in Various Countries and Future Building Plans

Mirai, an FC passenger vehicle that was launched in 2020.

This, the second-generation Mirai, was launched in December 2020 six years after the first-generation Mirai was released. Figure 4 shows the external appearance of the second-generation Mirai and Fig. 5 shows a perspective drawing of the vehicle. Table 3 compares the specifications of the first and second generations. The second-generation Mirai features major changes in layout from the first generation. These include the location of the FC system, which was moved to under the hood, the installation of a high-pressure hydrogen tank in the center tunnel, and the switch to rear-wheel drive. Measures such as increasing the hydrogen storage capacity from 4.(6) to 5.(6) and improving the efficiency of the system helped to achieve a cruising range (WLTC) of 850 km (reference value for the G grade model). Various innovative production engineering technologies involving the assembly of the FC cells, the aging process, the production of the high-pressure hydrogen tanks, quality inspections, and the like also helped to increase productivity by approximately 10 times compared to the first-generation Mirai, enabling an annual production capacity of around 30,000 vehicles.

Fig. 4 Second-Generation Toyota Mirai

Fig. 5 Perspective Drawing of Second-Generation Toyota Mirai (Direction of Movement Shown to the Right)

3. 3. Trends in FCEV Development (Heavy-Duty Vehicles)

This section focuses on heavy-duty FCEVs, which are being announced in growing numbers.

(1) Daimler Trucks

In September 2020, Daimler Trucks announced its next-generation FC truck concept called the GenH2 Truck. It announced a target to commercialize heavy-duty vehicles, FC systems, and the like through a joint project with the Volvo Group. The GenH2 Truck uses

Fig. 6 FC Stack Jointly Developed by Toyota and Hino

Table 3 Comparison of Specifications of First and Second Generation Mirai

Item		First-generation Mirai	Second-generation Mirai
Weight/performance	Vehicle weight (kg)	1,850	1,930
	Top speed (km/h)	175	
	WLTC fuel efficiency (km/kg)	—	135
	Cruising range (km, WLTC)	—	850
FC stack	Maximum power (kW)	114	128
	Number of cells	370	330
High-pressure hydrogen tanks	Number of tanks	2	3
	Tank capacity (L)	122.4	141
	Nominal working pressure (MPa)	70	
Drivetrain		Front wheels	Rear wheels
Motor	Maximum power (net, kW)	113	134
	Maximum torque (net, N·m)	335	300
Traction battery	Type	Nickel-metal hydride	Lithium-ion
	Capacity (Ah)	6.5	4
Occupant capacity		4	5

Fig. 7 FC Truck Jointly Developed by Toyota and Hino for North America

liquid hydrogen and has a maximum cruising range of 1,000 km. It is equipped with two 150 kW FC systems and a 400 kW secondary battery, and is driven by two motors. The gross vehicle weight of the GenH2 Truck is 40 tons, and its maximum carrying capacity is 25 tons. Demonstration testing is due to start in 2023, with mass-production penciled in for the second half of the 2020s.

(2) Toyota and Hino

(a) On March 23, 2020, these two companies announced the joint development of an FC truck (gross vehicle weight: 25 tons, Fig. 6). Based on the Hino Profia, this truck is equipped with two FC stacks from the second-generation Mirai and has a target cruising range of 600 km. It is planned to start demonstration testing of this FC truck in the Spring of 2022 for logistics work in the Tokyo metropolitan area and Aichi Prefecture.

(b) On October 5, 2020, the two companies also announced the joint development of an FC truck for North America. The size of the truck will be based on Hino's XL series (classes 7 and 8, Fig. 7). A prototype vehicle was developed in the first half of 2021 and evaluations are ongoing.

(3) Mitsubishi Fuso Truck and Bus

On March 26, 2020, Mitsubishi Fuso Truck and Bus announced that it plans to start the mass-production of FC trucks by the second half of the 2020s. The eCanter F-Cell concept truck has a gross vehicle weight in the 7.5-ton class, a maximum cruising range of 300 km, and a hydrogen refueling time of less than 10 minutes. Customers will be able to select an FCEV or BEV version of the eCanter depending on the usage scenario.

(4) Isuzu Motors Limited and Honda R&D Co., Ltd.

On January 15, 2020, these two companies announced the signing of a joint research contract for trucks using an FC powertrain. The aim of this research is to build a basic technological foundation including FC powertrain systems and vehicle controls.

(5) Hyundai Motor Company

In 2020, Hyundai rolled out fifty units of its Xcient FC truck, with plans to reach 1,600 units by 2025. The Xcient is equipped with a 190 kW FC system and can travel around 400 km on a single charge.

3. 4. Trends in FC Train Development

Outside the automotive field, studies are also examining the feasibility of installing FCs in other large means of transportation, including trains, ships, and aircraft. This section describes several examples of commercialization projects for trains. As countries around the world continue to promote the reduction of greenhouse gases, the adoption of FC trains is being pushed as a measure to replace diesel trains on non-electrified railroads.

(1) Development of FC Trains in Japan

More than 60% of Japan's railroad network is electrified, one of the highest rates in the world. Japan has acted quickly in the development of FC trains and, on October 6, 2020, Toyota, the East Japan Railway Company, and Hitachi, Ltd. announced the joint development of HYBARI, an FV-E991 series train equipped with a hybrid hydrogen FC system. These three companies are aiming to start demonstration testing on the Nambu and Tsurumi lines in around March 2022.

(2) Development Trends for FC Trains outside Japan

In 2018, the world's first FC train began operating in Germany. Built by the French company Alstom SA, this train has a top speed of 140 km/h and can run for 1,000 km after a single hydrogen refueling. The German company Siemens has also entered the FC train field and plans to start testing an actual train in 2024. In September 2020, the UK Department for Transport started testing of an FC train as part of its initiatives to meet government targets for zero net carbon dioxide emissions by 2050. In China, production of the world's first FC hybrid tram started in 2016.

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