Hybrid Vehicles, Electric Vehicles, Fuel Cell Electric Vehicles

1 Hybrid Vehicles

1. 1. Introduction

The demand for vehicles with better fuel efficiency and cleaner exhaust emissions is growing in light of rising fossil fuel prices and environmental problems such as air pollution and global warming. Automakers have been working to expand the number of vehicle models equipped with hybrid systems as one way of addressing this demand. Japanese manufacturers have focused on fuel-efficient hybrid electric vehicles (HEVs), which combine an internal combustion engine with an electric motor. Plug-in hybrid vehicles (PHEVs), which can be recharged via an external electric power source, have also been sold in Japan since 2012. Section 1 of this article describes the trends in HEVs that occurred in 2013.

1. 2. Popularization of HEVs in Japan

Figure 1 shows that the number of HEVs on the roads in Japan is increasing year after year. The number of hybrid passenger vehicles increased by 800,000 in 2012 and now clearly exceeds 2 million vehicles. The number of trucks and other non-passenger vehicles is also expanding steadily. PHEVs are becoming more popular and there are already around 17,000 on the road. This number should continue to expand in the future as automakers expand their PHEV line ups.

1. 3. New HEVs launched in Japan in 2013

Table 1 lists the hybrid passenger vehicles launched in Japan in 2013 by the month of launch. The main trends were as follows.

In January, Lexus launched an updated version of the HS250h. Changes to the hybrid system controls and higher charging efficiency improved fuel economy to 22.4 km/L in the JC08 test cycle.

In May, Lexus launched the completely re-designed IS series, featuring the IS300h with a 2.5-liter inline 4-cylinder engine and system power of 162 kW.

In June, Honda Motor Co., Ltd. launched the new Accord Hybrid. The Sport Hybrid i-MMD model is capable of starting off and low to medium speed cruising on motor power alone. On acceleration, the motor powers the vehicle with the engine acting as a generator. During high-speed cruising, the vehicle is mainly powered by the engine. This configuration enables fuel economy of 30.0 km/L (JC08 test cycle).

On the same day, Honda also launched the Accord Plug-in Hybrid that can be charged from household power outlets. Based on the Accord Hybrid, this PHEV has an electric vehicle (EV) mode range of 37.6 km and a plug-in combined fuel economy of 70.4 km/L (JC08 test cycle).

Also in June, Fuji Heavy Industries launched the Subaru XV Hybrid. Subaru's first hybrid system has a four-wheel drive (4WD) configuration that features a 2.0-liter horizontally opposed 4-cylinder engine and symmetrical all-wheel drive (AWD). Effective use of the motor to assist engine drive achieves a dynamic acceleration feel with fuel economy of 20.0 km/L (JC08 test cycle).

In July, Nissan Motor Co., Ltd. introduced the updated Fuga Hybrid. Higher motor torque and other improvements to the hybrid system enabled an expanded EV mode range and boosted fuel economy to 18.0 km/L (JC08 test cycle).

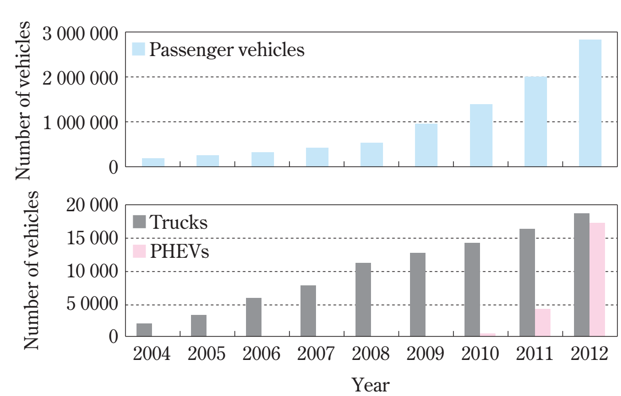


Fig. 1 Trends for number of HEVs on the road in Japan.

In August, Toyota Motor Corporation launched the completely re-designed Corolla, including the Corolla Hybrid with a 1.5-liter inline 4-cylinder engine and system power of 73 kW.

In the same month, Toyota also launched the updated Sai. Changes to the hybrid system controls and higher charging efficiency improved fuel economy to 22.4 km/L (JC08 test cycle).

In September, Honda launched the completely re-designed Fit, including a model installed with the one-motor SPORT HYBRID Intelligent Dual Clutch Drive (i-DCD) system. Despite only having a single motor, this system is capable of disengaging the engine and the motor to enable the vehicle to be driven as an EV on motor drive alone. This hybrid system combines a 1.5-liter inline 4-cylinder Atkinson cycle engine, a 7-speed dual

Table 1 Hybrid passenger vehicles launched in Japan in 2013.

								
Date announced/went on sale		2013/1/24	2013/5/16	2013/6/21		2013/6/24	2013/7/18	2013/8/6
Name of company		Lexus		Honda		Fuji Heavy Industries	Nissan	Toyota
Name of vehicle		HS250h	IS300h	Accord Hybrid	Accord Plug-in Hybrid	Subaru XV HEV	Fuga Hybrid	Corolla Hybrid
Type of hybrid system		Series-parallel	Series-parallel	Series-parallel	Series-parallel	Parallel	Parallel	Series-parallel
Drivetrain		Front-wheel drive	Rear-wheel drive	Front-wheel drive	Front-wheel drive	Four-wheel drive	Rear-wheel drive	Front-wheel drive
Fuel economy (JC08 test cycle, km/L)		22.4	23.2	30.0	29.0	20.0	18.0	33.0
Engine	Model	2AZ-FXE	2AR-FSE	LFA	LFA	FB20	VQ35HR	1NZ-FXE
	Displacement (cc)	2 362	2 493	1 993	1 993	1 995	3 498	1 496
	Power (kW)	110	131	105	105	110	225	54
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor
	Power (kW)	105	105	124	124	10	50	45
Battery	Type	Nickel-metal hydride	Nickel-metal hydride	Lithium-ion	Lithium-ion	Nickel-metal hydride	Lithium-ion	Nickel-metal hydride
	Capacity (kWh)	1.6	1.5	1.3	6.7	1.6	1.4	0.9

								
Date announced/went on sale		2013/8/29	2013/9/5	2013/9/9	2013/10/17	2013/11/13	2013/11/21	2013/12/2
Name of company		Toyota	Honda	Toyota	Lexus	Toyota	Mazda	Toyota
Name of vehicle		Sai	Fit Hybrid	Crown Majesta	GS300h	Harrier Hybrid	Axela Hybrid	Aqua
Type of hybrid system		Series-parallel	Parallel	Series-parallel	Series-parallel	Series-parallel	Series-parallel	Series-parallel
Drivetrain		Front-wheel drive	Front-wheel drive	Rear-wheel drive	Rear-wheel drive	Four-wheel drive	Front-wheel drive	Front-wheel drive
Fuel economy (JC08 test cycle, km/L)		22.4	36.4	18.2	23.2	21.8	30.8	37.0
Engine	Model	2AZ-FXE	LEB	2GR-FXE	2AR-FSE	2AR-FXE	PE-VPH	1NZ-FXE
	Displacement (cc)	2 362	1 496	3 456	2 493	2 493	1 997	1 496
	Power (kW)	110	81	215	131	112	73	54
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor
	Power (kW)	105	22	147	105	105	60	45
Battery	Type	Nickel-metal hydride	Lithium-ion	Nickel-metal hydride	Nickel-metal hydride	Nickel-metal hydride	Nickel-metal hydride	Nickel-metal hydride
	Capacity (kWh)	1.6	0.9	1.9	1.5	1.6	1.3	0.9

Table 1 Hybrid passenger vehicles launched in Japan in 2013 (cont.).

							
Date announced/went on sale		2013/12/20	2013/12/25	2013/2/1		2013/5/14	2013/10/1
Name of company		Honda	Nissan	Audi		Mercedes-Benz	
Name of vehicle		Vezel Hybrid	Serena S-Hybrid	A8 Hybrid	Q5 Hybrid	E400 Hybrid	S400 Hybrid
Type of hybrid system		Parallel	Parallel	Parallel	Parallel	Parallel	Parallel
Drivetrain		Front-wheel drive	Front-wheel drive	Front-wheel drive	Four-wheel drive	Rear-wheel drive	Rear-wheel drive
Fuel economy (JC08 test cycle, km/L)		27.0	16.0	13.8	12.7	15.2	15.4
Engine	Model	LEB	MR20DD	—	—	276	276
	Displacement (cc)	1 496	1 997	1 984	1 984	3 497	3 497
	Power (kW)	97	108	155	155	225	225
Motor	Type	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor	AC synchronous motor
	Power (kW)	22	1.8	40	40	20	20
Battery	Type	Lithium-ion	Lead-acid	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
	Capacity (kWh)	0.9	—	1.3	1 .3	—	—

clutch transmission (DCT) with a built-in motor, and a lithium-ion (Li-ion) battery. The SPORT HYBRID i-DCD achieves three separate driving modes (EV mode, hybrid mode, and engine-only mode) by engaging and disengaging the engine and motor in accordance with the driving state. The lineup also includes front-wheel drive (FWD) and 4WD variants.

Also in September, Toyota launched the completely re-designed Crown Majesta featuring a 3.5-liter V6 engine and system power of 252 kW.

In October, Lexus added the GS300h with a 2.5-liter inline 4-cylinder engine and system power of 162 kW.

In November, Toyota also launched the new Harrier model. The Harrier Hybrid features a 2.5-liter inline 4-cylinder engine and 4WD with a 50 kW motor installed at the rear. System power is 145 kW.

Also in November, Mazda Motor Corporation launched the completely re-designed Axela. The Axela Hybrid features a 2.0-liter inline 4-cylinder engine and a hybrid system based on the one used in the Toyota Prius.

In December, Toyota released an updated version of the Aqua. The efficiency of the hybrid system was improved by reducing engine friction and improving the motor/inverter controls, boosting fuel economy to 37.0 km/L (JC08 test cycle).

Also in December, Honda launched the Vezel, which uses the same one-motor SPORT HYBRID i-DCD system as the Fit. System power is 112 kW and the lineup also includes FWD and 4WD variants.

In the same month, Nissan introduced the updated Serena S-Hybrid with improved fuel economy of 16.0 km/L (JC08 test cycle).

Several HEV models were launched by non-Japanese manufacturers in Japan in 2013 as official imports. The Audi A8 Hybrid was introduced in February with a 2.0-liter inline 4-cylinder turbocharged engine and system power of 180 kW. Audi also launched the Q5 hybrid on the same day with the same system as the A8 hybrid and 4WD.

In May, Mercedes-Benz launched the E400 Hybrid featuring a 3.5-liter V6 engine. This model fits the Li-ion batteries under the hood, ensuring the same interior space as the conventionally powered version.

In October, Mercedes-Benz followed this launch with the S400 Hybrid, which uses the same system as the E400 Hybrid.

1. 4. Trends in standardization

ISO/TSC22/SC21 has been carrying out standardization activities for general vehicles that are powered by electricity, including HEVs, fuel cell vehicles (FCEVs), and battery electric vehicles (BEVs). The main trend in these activities has been the creation of fuel consumption measuring methods for all HEVs (ISO 23274-1 and 23274-2) in WG 2, which is the group that handles general performance. This includes both HEVs with and without external charging functions. Both of these testing

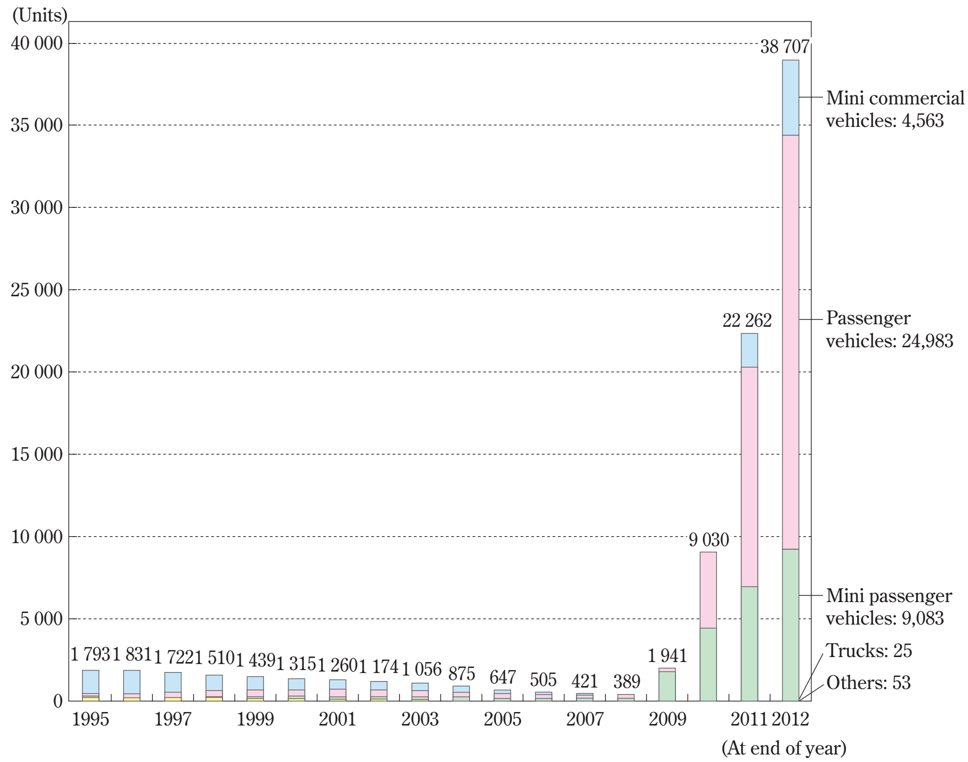


Fig. 2 Number of EVs in Japan.

methods were proposed by Japan and the Final Draft International Standard (FDIS) voting for ISO 23274-1 (revised), which is the standard for vehicles without an external charging function, was finished by the deadline on December 10. This standard was issued on January 13, 2013. ISO 23274-2, which is the standard for vehicles with an external charging function, was issued on July 26, 2012.

2 Electric Vehicles

2. 1. Introduction

Several years have passed since the latest wave of full-scale launches of mass-produced EVs in Japan in 2009. Despite excellent environmental performance and energy efficiency, the popularity of EVs remains limited. This is partly due to the fact that existing issues related to cost, cruising range, charging time, and available infrastructure have yet to be resolved. However, positive developments have occurred despite these issues. Front-runners in the EV field such as Nissan and Mitsubishi Motors Co., Ltd. have reduced the price of their vehicles. In addition, the Japanese government has actively worked to further promote the introduction of EVs into the market by expanding the available charging infrastructure, as well as by encouraging technological development and launching budgetary and tax measures to improve performance and reduce cost. As a result, EVs have started to gain more momentum. Section 2 of this article describes the initiatives taken in 2013 to further popularize EVs and the trends in standardization.

2. 2. Popularization of EVs

2. 2. 1. Market introduction and sales

Figure 2 shows the number of EVs on the roads in Japan, excluding motor-driven cycles and mini-vehicles [10].

The number of such vehicles in Japan decreased each year up to 2008. This trend changed in 2009 when Mitsubishi and Fuji Heavy Industries began sales of two small EVs, the i-MiEV and the Plug-In Stella, respectively. This increased the number of EVs in Japan to 1,941 vehicles by the end of 2009. In 2010, this number climbed further to 9,030 vehicles after the launch of the Leaf by Nissan. In 2011, Mitsubishi Motors expanded the variety of available i-MiEV models. In 2012, Honda developed the Fit EV, Mazda developed the Demio EV, and Toyota developed the eQ. All of these EVs were made available for lease. In April 2013, Nissan launched an updated version of the Leaf with a longer cruising range and lower price. In November 2013, Mitsubishi

Table 2 Specifications of main EVs launched by Japanese manufacturers.

		Mitsubishi i-MiEV M/X	Mitsubishi Minicab-MiEV	Mitsubishi Minicab-MiEV (truck version)	Nissan Leaf S	Mazda Demio EV	Honda Fit EV	Toyota eQ
External appearance								
Occupant capacity		4	2 (4)	2	5	5	5	4
Length × width × height		3 395×1 475 ×1 610 mm	3 395×1 475 ×1 915 mm /1 810 mm	3 395×1 475 ×1 820 mm	4 445×1 770 ×1 550 mm	3 900×1 695 ×1 490 mm	4 115×1 720 ×1 580 mm	3 115 × 1 680 × 1 535 mm
Cruising range		120 km/180 km (JC08)	100 km/150 km (JC08)	110 km (JC08)	228 km (JC08)	200 km (JC08)	225 km (JC08)	100 km (JC08)
Motor		30 kW/47 kW	30 kW	30 kW	80 kW	75 kW	92 kW	47 kW
Electricity consumption		110 Wh/km	125 Wh/km	120 Wh/km	114 Wh/km	100 Wh/km	106 Wh/km	104 Wh/km
Battery		Li-ion 10.5 kWh/16 kWh	Li-ion 10.5 kWh/16 kWh	Li-ion 10.5 kWh	Li-ion 24 kWh	Li-ion 20 kWh	Li-ion 20 kWh	Li-ion 12 kWh
Charging time	Normal	Single phase 100 V：14 h/21 h 200 V：4.5 h/7 h	Single phase 100 V：14 h/21 h 200 V：4.5 h/7 h	Single phase 100 V：14 h 200 V：4.5 h	Single phase 200 V：8 h	Single phase 200 V：8 h	Single phase 200 V：6 h	Single phase 200 V：3 h
	Rapid	DC 500 V：15 minutes/30 minutes (80 %)	DC 500 V：15 minutes/35 minutes (80 %)	DC 500 V：15 minutes (80 %)	DC 500 V：30 minutes (80 %)	DC 500 V：40 minutes (80 %)	DC 500 V：20 minutes (80 %)	DC 500 V：15 minutes (80 %)
Price (tax included)		2.4591 million yen to 2.90115 million yen	2.1651 million yen to 2.59875 million yen	From 1.858 million yen	From 2.98935 million yen	3.577 million yen	4.0 million yen	3.6 million yen

also launched a new grade of the i-MiEV with a lower price. The lineup of i-MiEV mini-vehicles also features commercial models such as the Minicab-MiEV. A van version was launched in December 2011 and a truck version was launched in January 2013. The number of EVs in Japan has continued to increase since the latest wave of full-scale launches of mass-produced EVs in 2009. By the end of 2012 the number of such vehicles had reached 38,707. Table 2 shows the specifications of each of these EVs.

2. 2. 2. Evolution of new vehicle categories

A new trend in recent years is the development of ultra-compact vehicles, which are smaller than mini-vehicles and seat two occupants. In addition to being easy to handle, the fact that most ultra-compact vehicles are EVs means that these vehicles are regarded as a promising means of addressing environmental issues and saving energy. Combining these vehicles with urban planning may help to achieve a low-carbon society and improve quality of life and mobility. This new category of vehicles has potential as a new form of urban and local transportation, while providing a boost to tourism and regional regeneration, and supporting the mobility of the elderly and child-raising families. The Japanese government and automakers have already moved to carry out joint field tests with local authorities with the aim of achieving market launch.

Specific examples of development and field tests are as follows. In November 2010, Nissan unveiled the New Mobility Concept, which was launched as the Renault Twizy in Europe in 2012 and used in car sharing schemes and other field tests in Yokohama. In July 2012, Toyota Auto Body Co., Ltd. began selling a new version of the COMS, which is being used for new services, such as a delivery service vehicle for Seven-Eleven Japan. At the 43rd Tokyo Motor Show in November 2013, Honda unveiled the MC-β, which has been used in public trials in Kumamoto Prefecture and Saitama city. Honda has also begun working on ways to achieve local consumption of locally generated energy on remote islands, such as constructing electricity supply infrastructure for ultra-compact vehicles using solar power on Miyakojima in Okinawa. These trends show that EVs are more than straight alternatives for existing vehicles and the potential of applying electrification to other categories cannot be denied. Automakers and venture companies are focusing their knowledge on ways to expand the application of EVs from various standpoints, efforts that have

Table 3 Specifications of main ultra-compact vehicles.

Manufacturer/ type	Nissan New Mobility Concept	Toyota Auto Body COMS	Honda MC-β
External appearance			
Occupant capacity	2	1	2
Length × width × height	2 340×1 230×1 450 mm	2 395×1 095×1 500 mm	2 495×1 280×1 545 mm
Maximum speed	80 km/h	60 km/h	70 km/h
Cruising range	100 km	50 km	80 km
Rated power	8 kW	0.59 kW	6 kW
Battery	Lithium-ion	Lead (5.2 kWh)	Lithium-ion
Charging method/time	AC 200 V/4 hours	AC 100 V/6 hours	AC 100 V/7 hours AC 200 V/3 hours
Vehicle weight	450 kg	410 kg	—
Price (tax included)	—	668,000 yen to 798,000 yen	—

resulted in new proposals and initiatives. Table 3 lists the specifications of the main ultra-compact vehicles unveiled in Japan.

In addition, the Japanese Ministry of Land Infrastructure and Transport (MLIT) is examining ways of ensuring the safety of ultra-compact vehicles, which are mainly used over short distances as a simple and convenient means of local transportation. It has introduced relaxed standards based on the Safety Regulations for Road Vehicles under the Road Trucking Vehicle Law. These prohibit the driving of ultra-compact vehicles on expressways, restrict usage to locations capable of ensuring safe and smooth traffic flows, and apply conditions for size and performance. These measures allow a relaxing of some regulations providing that safety and environmental performance is not adversely affected. These standards were established in January 2013 and allow ultra-compact vehicles to be driven on public roads.

As a result, it is hoped that ultra-compact vehicles will help to create new markets as an innovative and energy saving vehicle category in a country facing up to a declining birth rate and an aging population, using the particular benefits of EVs.

2. 3. Initiatives to expand EV usage

2. 3. 1. Initiatives of national and local governments

In April 2010, the Japanese Ministry of Economy, Trade and Industry (METI) released its Next Generation Vehicle Strategy 2010. This strategy laid out the government's targets for each vehicle type (i.e., the proportion of each type within new vehicle sales) for accelerating the popularization of EVs and other next-generation vehicles. The achievement of these targets requires a proactive incentive policy from the government, encompassing support for development and purchase, taxation, and infrastructure). The Japan Revitalization Strategy released by the Cabinet In June 2013 contains a policy item called, "Supporting dissemination and improving performance of next-generation automobiles." Targets within this policy include increasing the proportion of next-generation vehicle sales to 50% of new vehicle sales by 2020, establishing 2 million regular and 5,000 rapid charging stations, and further increasing the proportion of next-generation vehicle sales to between 50 and 70% of new vehicle sales by 2030.

For EVs, establishing a wider charging infrastructure is as important as popularization. Since 2009, METI has provided incentives both for promoting the introduction of clean energy vehicles to help reduce the burden of purchasing an EV and for establishing charging stations. In 2013, it reinforced this two-pronged approach by introducing two new support initiatives: the Next-generation Electric Vehicle Charging Infrastructure Establishment Promotion Project (scale: 100.5 billion yen), and the aforementioned incentives for promoting the introduction of clean energy vehicles (scale: 30.0 billion yen). The aim of these initiatives is to help companies provide vehicles and charging facilities, to stimulate initial demand, and to promote price reductions through the effect of mass-production. One feature of these latest initiatives is support for the installation as well as the purchase of chargers, providing that certain charging infrastructure conditions are met. The period of the promotion projects was also extended by a year up to the end of February 2015. METI is also promoting a model project called the EV/PHV Town concept. METI has selected 18 local authorities in Japan that are leading the way toward the popularization of EVs and PHEVs. The aim is to build a popularization model for next-generation vehicles, also incorporating charging infrastructure, through a targeted approach, and then roll out the model nationwide.

These are examples of the activities being carried out on a national and local level to help expand the popularity and use of EVs. As a result, the spread of EVs is starting to gain traction as the number of available charging stations increases to offset restrictions in cruising range.

2. 3. 2. Initiatives of private companies

As of September 2013, there were still only 1,900 rapid and 3,500 regular charging stations in Japan. Due to this low number of charging stations and insufficient compatibility between the multiple available charging stations, the convenience of EVs still has room for improvement.

In July 2013, partially as a result of this situation, four automakers (Toyota, Nissan, Honda, and Mitsubishi) agreed to jointly promote activities to establish charging stations and to build a convenience charging network service. The specific details of the support to be offered to infrastructure providers were settled in November of the same year. Since government incentives cannot completely cover the cost of the charging infrastructure, the four automakers agreed to support the costs of infrastructure providers to help improve the convenience of drivers through EVs. Specifically, this initiative focused on certain public charging stations based on the incentive concepts formulated by local authorities. Out of these, the automakers agreed to shoulder some of the installation and maintenance costs of chargers installed in commercial facilities meeting certain conditions, for example charging stations at popular travel destinations such as shopping and accommodation facilities, as well as charging stations along main routes such as expressway service and parking areas, convenience stores along main roads, and gas stations. These four automakers also plan to establish a membership-based charging service in the summer of 2014.

2. 4. Trends in standardization

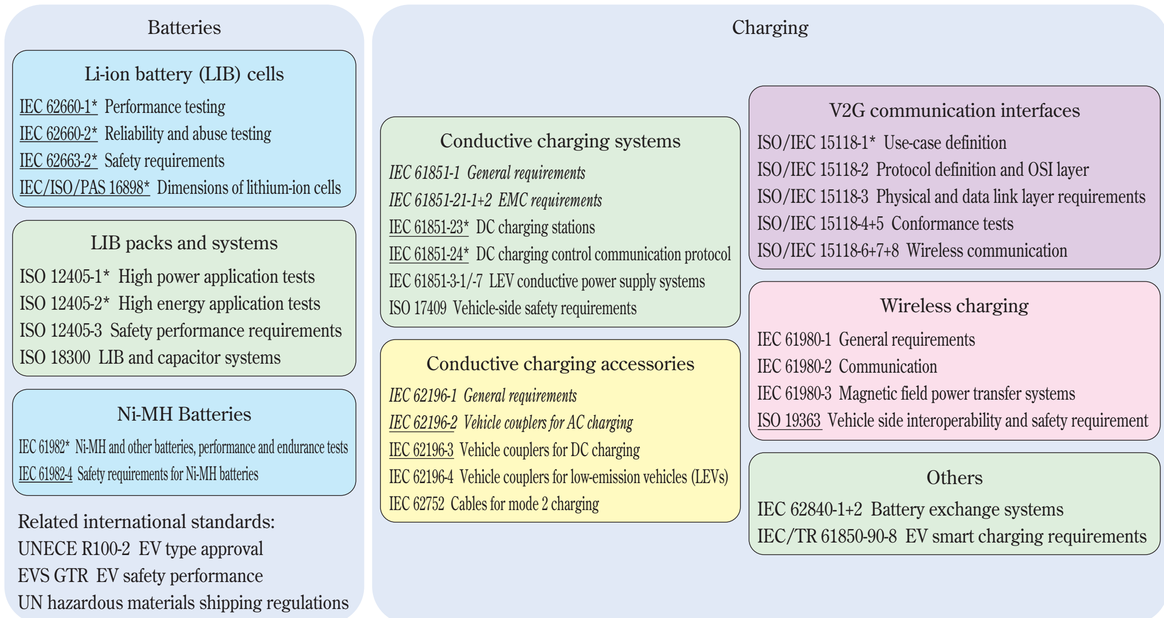
As described above, EVs are beginning to enter the period of mass popularization. The establishment of international standards for related technology is one of the critical tasks to facilitate this progress. Formulating appropriate international standards and compatibility from the standpoint of the global market is particularly important for chargers and other infrastructure and related equipment crucial for popularizing EVs.

The Japan Automobile Research Institute (JARI) undertakes activities such as the standardization of technologies and components related to EVs. Figure 3 shows the composition of the main international standards and draft standards that currently concern EV batteries and battery charging.

As a part of its initiatives concerning batteries, Japan proposed performance tests for Li-ion secondary batteries (cells) for EVs (IEC 62660-1) and reliability and abuse tests (IEC 62660-2) to the IEC. Both of these were issued as international standards in December 2010. The standard for safety requirements (IEC 62660-3) is currently under discussion. In addition, Germany proposed test methods for Li-ion battery packs and systems for EVs to the ISO. The high power application tests (ISO 12405-1) were issued as an international standard in August 2011 and the high energy applications tests (ISO 12405-2) were issued as an international standard in July 2012. The safety performance requirements (ISO 12405-3) are still under discussion. Furthermore, Japan also proposed the first draft international standard related to the safety requirements of nickel-metal hydride (NiMH) batteries for EVs (IEC 61982-4). Discussion of this standard began in August, 2013.

Li-ion batteries are also subject to UN regulations when shipped via aircraft or marine vessels. Since applying these regulations to large automotive Li-ion batteries would result in excessive testing, activities are being carried out to rationalize shipping regulations.

The following international standards related to charging were published in March 2014 based on proposals from Japan: DC charging stations (IEC 61851-23) and digital communication for DC charging control (IEC 61851-24). Other standards based on proposals from Japan are still under discussion, such as dimensional compatibility and interchangeability requirements for vehicle DC char-



(Note) Standards marked with an asterisk (*) have already been issued. Standards in *italics* are currently under discussion for revision. Other standards are at the first discussion phase. Underlined standards were initially proposed by Japan.

Fig. 3 International standards and draft standards related to batteries and charging.

gers (IEC 62196-3), general requirements for conductive charging systems, vehicle-to-grid (V2G) communication interfaces, and general requirements for wireless power supply systems.

3 Fuel Cell Electric Vehicles (FCEVs)

3. 1. Introduction

Fueled by hydrogen and with zero CO_2 emissions, FCEVs are regarded as an ultimate type of environmentally friendly vehicle with a strong potential for widespread popularization. Obviously, the establishment of hydrogen fueling stations is a perquisite for this. Therefore, the Fuel Cell Commercialization Conference of Japan has proposed a roadmap for the number of FCEVs and hydrogen stations as a scenario to promote popularization. According to this roadmap, FCEVs should start gaining acceptance with general users from 2015. By 2025, the roadmap envisions about 2 million FCEVs and roughly 1,000 hydrogen stations in Japan under the assumption that growth will reach self-sustainable levels. As is the case for EVs, FCEVs can be provided with an external power supply function, enabling use as a power generator in emergencies. Section 3 of this article describes the main trends in FCEV development and hydrogen fuel infrastructure that occurred in 2013.

3. 2. Trends in FCEV research and development

Japan's three largest automakers have announced that the planned commercial launch of FCEVs in the future, Toyota and Honda in 2015, and Nissan in 2017 at the earliest. As these launch dates approach, each company is strengthening ties with non-Japanese automakers and increasing the efficiency of research and development through technical tie-ups with the ultimate aim of reducing FCEV costs. The following sections outline the research and development trends for FCEVs, focusing on information released by each company.

3. 2. 1. Toyota

On January 24, 2013, Toyota announced that it had signed a binding agreement with BMW to collaborate in the development of fuel cell (FC) systems. The two companies agreed to share their technologies and to jointly develop a fundamental FCEV system, including not only a FC stack and system, but also a hydrogen tank, motor and battery, aiming for completion in 2020.

On November 5, 2013, Toyota announced that it would exhibit a next-generation FCEV at the 43rd Tokyo Motor Show. The vehicle that was unveiled at the show was a sedan called the Toyota FCV Concept (Fig. 4). This FCEV uses Toyota's own new compact and lightweight FC stack and features two 70 MPa high-pressure hydrogen tanks under the floor.

The power density of this FC stack is 3 kW/L, more

Fig. 4 Toyota FCV Concept.

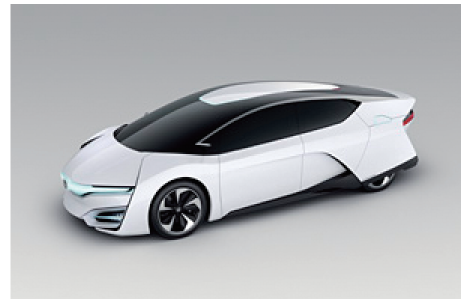


Fig. 5 Honda FCEV Concept.

Fig. 6 New Honda FC stack.

than twice that of the stack in the previous Toyota FCHV-adv model, and the system power is more than 100 kW. Using a high-efficiency boost converter in the FC system to increase the voltage allows the size of the motor and the number of fuel cells to be reduced. The real-world cruising range of this FCEV is more than 500 km. It can also be fully re-fueled in around three minutes, similar to the time required to fill up a gasoline vehicle. The external power supply function can provide enough electricity to meet the daily needs of an average Japanese home (10 kWh) for more than one week.

3. 2. 2. Nissan

On January 28, 2013, Renault-Nissan signed an agreement with Daimler and Ford to accelerate the commercialization of FCEV technology. The goal of this collaboration is to reduce the related costs of developing FCEV technology through economies of scale, with the aim of launching the world's first affordable, mass-market FCEV. Nissan regards FCVs as complementary to EVs and should help to expand the range of zero-emission transportation options available to consumers.

3. 2. 3. Honda

On April 9, 2013, Honda announced the start of an experiment to power a home in Kitakyushu, Fukuoka Prefecture, using an FCX Clarity, as part of a joint test in the Kitakyushu Smart Community Project. The FCX Clarity connected to the house is provided with an external power system capable of supplying a maximum of 9 kW, enough for 6 days power supply for an average home. Using the power supplied by the FCX Clarity, this project is studying the leveling of power demand by cutting demand during peak periods to verify the CO_2 reduction effect in a real-world urban environment. The project is also verifying the practicality of the vehicle as a mobile generator in emergencies.

On July 2, 2013, Honda announced an agreement with GM to jointly develop next-generation FC systems. The two companies agreed to co-develop next-generation fuel cell system and hydrogen storage technologies with a target completion date of around 2020. Another key aim of this project is cost reduction.

Honda also gave a world premiere to the Honda FCEV Concept (Fig. 5), the successor to the FCX Clarity, at the 2013 Los Angeles Auto Show on November 21.

This FCEV is equipped with a FCEV stack that is roughly 33% smaller than the previous stack, and has a maximum power of more than 100 kW and a power density of more than 3 kW/L (Fig. 6). The Honda FCEV Concept uses 70 MPa hydrogen storage tanks and has a range of more than 300 miles. The tanks can be refueled in around 3 minutes. Honda plans to launch a commercial FCEV based on this concept in 2015.

3. 3. Trends in establishing hydrogen station infrastructure

On January 13, 2011, the three automakers mentioned above and ten infrastructure companies announced an agreement related to the Japanese market introduction of FCEVs and the establishment of a hydrogen supply infrastructure. This announcement contained a pledge to establish around 100 hydrogen stations in four major metropolitan areas by 2015. The popularization of

Fig. 7 Ebina Chuo Hydrogen Station.

FCEVs in the real-world relies on the easy availability of hydrogen fuel and hydrogen stations are required to build an equivalent refueling environment to gasoline vehicles.

On April 19, 2013, JX Nippon Oil and Energy Corporation opened Japan's first hybrid gasoline/hydrogen filling station in Ebina, Kanagawa Prefecture (Fig. 7). This station employs an off-site method in which hydrogen is transported in by dedicated trailers and stored in a pressure vessel at the station. The hydrogen supply capacity of the station is 300 Nm^3/h at a filling pressure of 70 MPa, which allows an FCEV to be refueled in roughly 3 minutes. This station was built based on a newly developed concept to reduce size, save space, and lower costs. Its example should help to reduce the building costs of other hydrogen stations in the future. Another aim is to quickly start up a hydrogen supply business for gasoline service stations by building up a base of working knowledge about hydrogen supply infrastructure.

Including this station, there are currently 12 active hydrogen stations in Japan. To achieve the goal of 100 stations by 2015, the relevant parties are working to relax the conditions of various regulations such as the High Pressure Gas Safety Act and allocate roughly 4.59 billion yen of incentives for the building of hydrogen stations.

3. 4. Conclusions

In 2013, Toyota and Honda unveiled the concepts that will form the basis of their commercial FCEVs. Other concrete steps toward the start of commercial sales in 2015 included the opening of new hydrogen stations. However, neither company has reached the stage of publicizing the price of these FCEVs, and continued efforts are probably under way to reduce costs. The widespread acceptance of FCEVs by customers also depends on building an extensive supply network, and more hydrogen stations should be established ahead of the important 2015 milestone.