
Hybrid Vehicles, Electric Vehicles, Fuel Cell Electric Vehicles

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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, also went on sale for the first time in Japan in 2012. The following sections will describe the trends in HEVs that occurred in 2012.

1.2. Popularization of HEVs

Fig. 1 shows the number of hybrid vehicles on the roads in Japan. The figure shows that the number of hybrid vehicles is increasing year after year and that the number of hybrid passenger vehicles now exceeds 2 million vehicles. It also shows that this number increased by 1 million vehicles in just the past 2 years.

There are two main reasons for this increase. One is the expanding number of vehicle models equipped with hybrid systems (Table 1) launched by Japanese automakers. The other is the policy of the Japanese government to promote the trade-in of older vehicles and the purchase of more fuel efficient vehicles through an incentive system and preferential tax scheme for environmentally friendly vehicles (i.e., preferential application of the motor vehicle weight tax and vehicle acquisition tax).

1.3. Trends in vehicle and technological development

Table 1 shows the hybrid passenger vehicles that were sold in Japan in 2012. The following section outlines the trends in technological development.

Nissan Motor Co., Ltd. started selling the Cima Hybrid

in April 2012. This is a version of the Fuga Hybrid with a longer wheelbase and the same hybrid system. Nissan's original parallel hybrid system that features one motor and two clutches, called intelligent dual clutch control, is used on these vehicles with a lithium-ion battery.

The Serena S-Hybrid went on sale in August. The S-Hybrid system uses an upgraded version of the ECO motor found in the existing Serena as an auxiliary motor to increase power and energy regeneration capabilities. A sub-battery that can fit in the current engine compartment was also added for increased power capacity, resulting in a simple and compact hybrid system. The entire hybrid system is mounted within the engine compartment.

Honda Motor Co., Ltd. debuted an updated version of the CR-Z in September 2012. Changes include the first use of a lithium-ion battery in a hybrid vehicle manufactured by Honda for the Japanese market. This new battery generates approximately 1.5 times the voltage of a conventional nickel-metal hydride battery, which increases the power of the motor.

In November 2012, Honda developed a new lightweight and compact hybrid system called the SPORT HYBRID Intelligent Dual Clutch Drive that uses a single motor and is optimized for small vehicles. This forms part of Honda's next-generation EARTH DREAMS TECHNO-

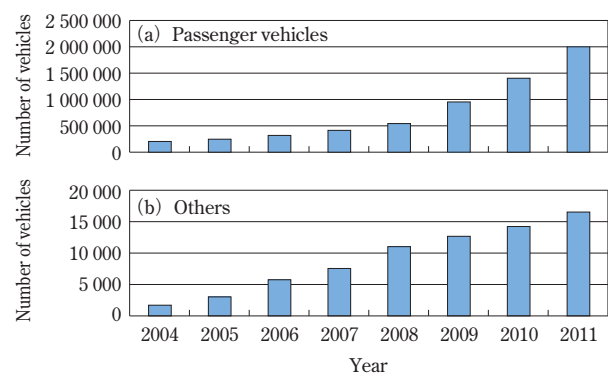


Fig. 1 Trends for number of HEVs on the road in Japan⁽¹⁾

Table 1 Hybrid passenger vehicles sold in Japan in 2012⁽²⁾⁻⁽⁵⁾

								
Date announced/ went on sale		2012/4/25	2012/8/1	2012/9/27	2012/1/30	2012/12/25	2012/3/19	2012/12/26
Name of company		Nissan Motor Co., Ltd.		Honda Motor Co., Ltd.	Toyota Motor Co., Ltd.		Lexus	Mitsubishi Motors Co., Ltd.
Name of vehicle		Cima Hybrid	Serena Hybrid	CR-Z	Prius PHV	Crown	GS450h	Outlander PHEV
Type of hybrid system		Series-parallel	Parallel	Parallel	Series-parallel			Series-parallel
Drivetrain		Rear wheel drive	Front wheel drive	Front wheel drive	Front wheel drive	Rear wheel drive	Rear wheel drive	Four-wheel drive
Fuel economy (JC08 test cycle, km/h)		16.6	15.2	21.6	31.6	23.2	18.2	18.6
Engine	Model	VQ35HR	MR20DD	LEA	2ZR-FXE	2AR-FSE	2GR-FXE	4B11 MIVEC
	Displacement (cc)	3 498	1 997	1 496	1 797	2 493	3 456	1 998
	Power (kW/rpm)	225	108	87/6 600	73/5 200	131/6 000	217/6 000	87/4 500
Motor	Type	AC synchronous motor		AC synchronous motor	AC synchronous motor			Permanent magnet synchronous
	Power (kW)	50	1.8	15	60	105	147	60×2
Battery	Type	Lithium ion	Lead acid	Lithium ion	Lithium ion	Nickel-metal hydride	Nickel-metal hydride	Lithium ion
	Capacity (kWh)	1.3		0.68	4.4	1.5	1.9	12



Fig. 2 EARTH DREAMS TECHNOLOGY⁽³⁾

OGY for powertrains (Fig. 2), which aims to further improve both driving performance and fuel efficiency. This new hybrid system for small vehicles combines a newly developed inline 4-cylinder 1.5-liter Atkinson cycle engine, a 7-speed dual clutch transmission with a built-in high-power motor, and a lithium-ion battery. This new drive unit is at least 30% more efficient than the conventional 1-motor hybrid system.

Honda developed the SPORT HYBRID Intelligent Multi Mode Drive as a two-motor hybrid system optimized for mid-size vehicles. This hybrid system combines a newly developed engine that is dedicated for use in hybrid vehicles, an electric CVT coupled with two

built-in motors and a lock-up clutch, and a lithium-ion battery. This system also optimally switches the driving mode among three different modes depending on the driving situation. It is also suitable for use in PHEV systems and will be equipped on the Accord in North America that was scheduled to go on sale in January 2013.

Honda has also developed the SPORT HYBRID SH-AWD as a three-motor hybrid system optimized for large vehicles, which can freely control the driving force on the left and right sides of the vehicle. The combination of a V6 engine and this high-power three-motor system realizes acceleration performance equivalent to a V8 engine with fuel efficiency that is better than an inline 4-cylinder engine. A new V6 3.5-liter direct-injection engine is mounted in the front of the vehicle and combined with a newly-developed 7-speed dual clutch transmission with a single built-in motor. The drive provided by the two motors mounted in the rear of the vehicle freely controls the torque distribution to the right and left rear wheels and helps to realize both excellent fuel efficiency and driving performance.

Toyota Motor Co., Ltd. introduced the Prius PHV to the market in January 2012. This was the first PHEV launched in Japan. The adoption of a new high-capacity

and high-power lithium-ion battery gives the Prius PHV an EV driving conversion distance (EV driving distance) of 26.4 km in EV mode with a fully charged battery. In addition, the PHEV mode fuel consumption (calculated as the composite of EV mode fuel efficiency and fuel consumption in HEV mode) is 61.0 km/L. The fuel efficiency in HEV mode after the battery charge is entirely used up is 31.6 km/L. The vehicle-mounted charger allows the battery to be completely recharged in approximately 90 minutes using an AC 200 V power source (or approximately 180 minutes using an AC 100 V power source).



The Toyota Crown went on sale in December 2012. A hybrid vehicle can be selected for each of the different grades of the Crown. The predecessor to the Crown Hybrid used a V6 engine, but this has been replaced with a 2.5-liter inline 4-cylinder Atkinson cycle engine. The combination of this engine with a high-torque motor allows this vehicle to achieve both power performance comparable to a V6 3.0-liter vehicle and excellent environmental performance at the top of its class.

The Lexus GS450h was introduced to the market in March 2012. This vehicle is equipped with the Lexus Hybrid Drive that achieves even further advanced performance through a combination of a newly developed 3.5-liter V6 Atkinson cycle engine and front-engine rear-wheel drive (FR) hybrid technology. This hybrid system achieves power performance comparable to a V8 gasoline engine.

Mitsubishi Motors Co., Ltd. launched the Outlander PHEV in December 2012. The Outlander PHEV has three driving modes: EV driving mode, series driving mode, and parallel driving mode. This enables the driver to select the environmentally friendly EV mode for everyday use, while using the motor-assisted hybrid modes for longer trips. The use of 2 motors and 4WD delivers excellent driving performance. In EV mode with a fully charged battery, the EV driving conversion distance (EV driving distance) is 60.2 km. The PHEV mode fuel consumption (see above) is 67.0 km/L. The fuel efficiency in HEV mode after the battery's charge has been entirely used up is 18.6 km/L. The battery can be charged up to 80% of capacity in approximately 30 minutes by a rapid charger. The battery can be fully charged in approximately 4 hours via an AC 200 V power source (or in approximately 13 hours using an AC 100 V power source) via normal charging with the vehicle-mounted charger.

Table 2 shows the hybrid commercial vehicles that

Table 2 Hybrid commercial vehicles sold in Japan in 2012^{(6) (7)}

			
Date announced/ went on sale		2012/5/18	2012/8/9
Name of company		Mitsubishi Fuso Truck and Bus Corporation	Isuzu Motors Limited
Name of vehicle		Canter Eco Hybrid	Erga Hybrid
Type of hybrid system		Parallel	Parallel
Drivetrain		Rear wheel drive	Rear wheel drive
Fuel economy (heavy duty vehicle test cycle, km/L)		12.8	4.9
Engine	Model	4P10	6HK1-TCC
	Displacement (cc)	2 998	7 790
	Power (kW/rpm)	96/3 050-3 500	191/2 400
Motor	Type	Permanent magnet synchronous	Permanent magnet synchronous
	Power (kW)	40	44
Battery	Type	Lithium ion	Lithium ion
	Capacity (kWh)	2	3.9

were sold in Japan in 2012. The following outlines the trends in the technological development of these vehicles.

Mitsubishi Fuso Truck and Bus Corporation was the first manufacturer in the world to adopt a dual clutch automatic transmission with a built-in motor, called DUONIC, on a commercial vehicle. In addition, the Canter Eco Hybrid system combines a new high-performance lithium-ion battery with the 4P10 diesel engine, and this system was introduced into the market in May, 2012. This is a parallel hybrid system in which an electric motor is placed between the clutch and transmission.

The Erga Hybrid from Isuzu Motors Limited went on sale in August 2012. It adopts a parallel hybrid system that allows the vehicle to be driven only by the electric motor when it accelerates from a stop. This system uses energy efficiently and is particularly suited to large buses that drive on fixed routes with frequent starting and stopping. This system also uses a lithium-ion battery with a high capacity and high input and power performance.

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 (FCVs), and battery electric vehicles (BEVs). The main trend in these activities has been the creation of fuel consump-

tion measuring methods for all HEVs (ISO 23274-1 and 23274-2) in WG2, which is the group that handles general performance. This includes both HEVs with and without external recharging functions. Both of these testing methods were proposed by Japan and the Final Draft International Standard (FDIS) voting for ISO 23274-1 (revised) was finished by the deadline on December 10. This standard was issued on January 13, 2013. ISO 23274-2 will be issued on July 26, 2013.

2 Electric Vehicles

2.1. Introduction

Several years have passed since electric vehicles (EVs) were first seriously re-introduced onto the market in 2009. EVs have excellent environmental performance and energy efficiency, and are garnering attention as next-generation environmentally friendly vehicles. However, issues include high cost, short cruising ranges, and the development and maintenance of a support infrastructure. Both Nissan Motor Co., Ltd. and Mitsubishi Motors Co., Ltd. have been active and early entrants into the EV field and are working to reduce the price of these vehicles. The Japanese government is also moving to expand charging facilities for EVs. Development of technologies that will increase the performance and lower the cost of these vehicles is progressing and other measures, such as budget and tax measures to further promote the introduction of EVs into the market are being actively pursued as well. The following sections outline the initiatives taken in 2012 to further popularize

EVs and the trends in standardization.

2.2. Popularization of EVs

2.2.1. Market introduction and sales

Fig. 3 shows the number of EVs on the roads in Japan, excluding motor-driven cycles and minicars⁽⁸⁾. The number of such vehicles in Japan decreased each year up to 2008. This trend changed in 2009 when Mitsubishi Motors 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. In 2010, this number climbed further to 9,030 vehicles after the launch of the Leaf passenger vehicle by Nissan. In 2011, Mitsubishi Motors expanded the variety of available i-MiEV models. In 2012, Honda Motor Co., Ltd. developed the Fit EV, Mazda Motor Corporation developed the Demio EV, and Toyota Motor Co., Ltd. developed the eQ. All of these EVs were subsequently released for sale. Nissan also started selling a partially revamped version of the Leaf in November 2012 with an extended cruising range to improve its product appeal. The number of EVs in Japan has continued to increase since the full-scale introduction of mass-produced EVs into the market in 2009. By the end of 2011 the number of such vehicles had reached 22,262. Table 3 shows the specifications of each of these EVs⁽⁹⁾⁻⁽¹³⁾.

2.2.2. Evolution of a new vehicle category

Outside the passenger vehicle category, Mitsubishi Motors announced the Minicab-MiEV (truck version) in December 2012. This is a mini-truck based on the Mitsubishi Minicab mini-truck and shares components from

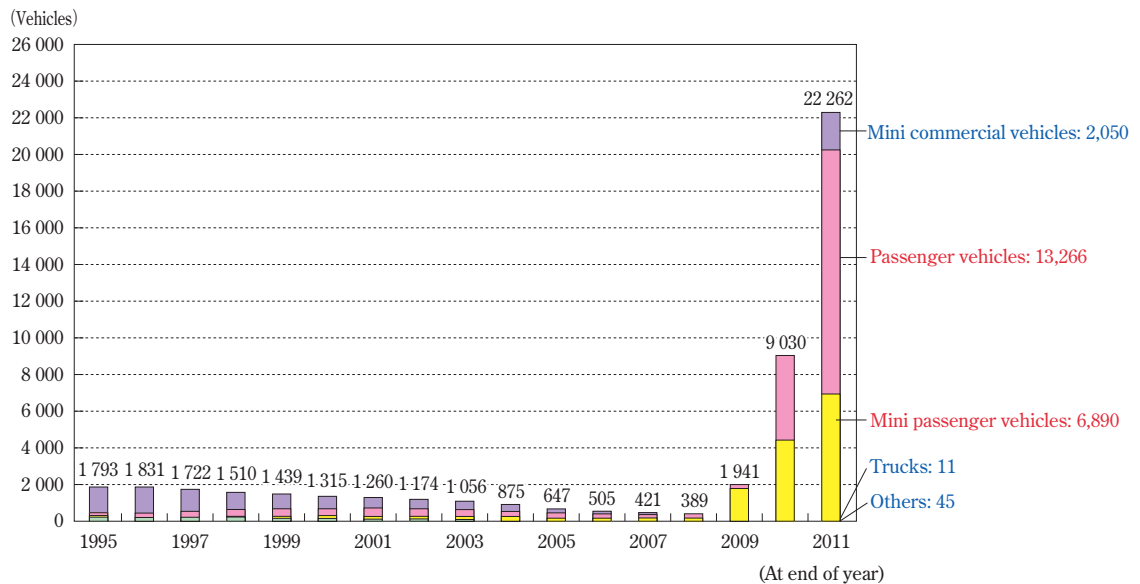









Fig. 3 Number of EVs in Japan.

Table 3 Specifications of i-MiEV M/G, Minicab-MiEV, Minicab-MiEV (truck version), Leaf, Demio EV, Fit EV, and eQ.

	Mitsubishi Motors Co., Ltd. i-MiEV M/G	Mitsubishi Motors Co., Ltd. Minicab-MiEV	Mitsubishi Motors Co., Ltd. Minicab-MiEV (truck version)	Nissan Motor Co., Ltd. Leaf S	Mazda Motor Corporation Demio EV	Honda Motor Co., Ltd. Fit EV	Toyota Motor Co., Ltd. eQ	
External appearance								
Occupant capacity	4	2 (4)	2	5	5	5	5	
Length × width × height	3 395 × 1 475 × 1 610 mm	3 395 × 1 475 × 1 915 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	4 445 × 1 770 × 1 545 mm	
Cruising range	120 km/180 km (JC08)	100 km/180 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	80 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%)
Cost (tax included)	2.6 million yen to 3.8 million yen	2.4 million yen to 2.971 million yen	1.858 million yen	3.276 million yen	3.577 million yen	4.0 million yen	3.6 million yen	

the i-MiEV and Minicab-MiEV (van version), such as the lithium-ion battery and electric motor⁽⁹⁾. The Minicab-MiEV (van version) was introduced in 2011 and its sales volume has increased with a focus on commercial applications.

In response to recent changes in the social environment, such as the low birth rate, aging population, and the decline in public transportation, there are continued expectations for the success of ultra-compact mobility vehicles. Consequently, all automakers are developing new vehicles and announcing concept cars. Nissan unveiled the New Mobility CONCEPT in November 2010 as one concrete move toward commercializing some of these vehicles, and it has begun test driving experiments on public roads within the city of 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. Table 4 shows the specifications of these ultra-compact mobility vehicles⁽¹⁰⁾⁽¹⁴⁾. At the same time, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) issued guidelines for the introduction of ultra-

Table 4 Specifications of Nissan's New Mobility CONCEPT and Toyota Auto Body's COMS

	Nissan New Mobility CONCEPT	Toyota Auto Body COMS
External appearance		
Length × width × height	2 337 × 1 191 × 1 461	2 395 × 1 095 × 1 500
Cruising range	100 km	50 km
Maximum speed	80 km/h	60 km/h
Occupant capacity	2	1
Battery	Lithium ion	Sealed lead acid battery for EV
Vehicle weight	450 kg	410 kg
Cost (tax included)	—	668,000 yen to 798,000 yen

compact mobility vehicles in June 2012 to summarize the relevant issues. These include methods of utilizing ultra-compact mobility vehicles and the social effects of introducing such vehicles⁽¹⁵⁾. MLIT also introduced a

certification system to enable ultra-compact mobility vehicles to be driven on public roads. Local governments and companies that use vehicles certified by MLIT for tourism and medical visits directly to patients homes will receive monetary assistance for half the cost of these vehicles starting in 2013.

As described above, EVs are not just being used as passenger vehicles, but are also evolving for use in commercial fields such as shipping and transport. The advent of ultra-compact mobility vehicles is developing a whole new category of vehicles in this age of energy efficiency, low birth rates, and an aging population. The spread and wider adoption of EVs is expected to create new vehicle markets.

2.3. Initiatives to expand EV usage

2.3.1. Initiatives of national and local governments to create demand and expand usage

On July 31, 2012 the Cabinet approved the Comprehensive Strategy for the Rebirth of Japan. This is a concrete proposal for stimulating Japan's economy that specifies 11 growth strategies and 38 priority policy actions. One of these priority policy actions is the Green Growth Strategy, which sets a target of increasing the percentage of next-generation vehicles to 50% of all new vehicle sales by the year 2020. The introduction of these next-generation vehicles will receive government support to accelerate adoption and to create a new market for ultra-compact mobility vehicles. These next-generation vehicles are being positioned as one of the leading central projects of green growth in the comprehensive strategy. The Ministry of Economy, Trade and Industry (METI) has decided to offer incentives for promoting the introduction of clean energy vehicles in an effort to create initial demand for these vehicles by reducing the burden of vehicle purchase and charging facility establishment. METI is also aiming to promote price reductions through the effect of mass-production.

Local governments are also taking actions to promote EV usage, such as by reducing taxes and providing discounts on parking fees for EVs. Aichi Prefecture and Fukuoka Prefecture have established additional incentives for EVs. In addition, METI has begun selecting some local governments that are pioneering initiatives to promote the spread and adoption of EVs as model regions (so-called EV and PHV Towns). In August 2010 METI collected together various progressive initiatives to promote the spread of EVs and PHVs into the EV &

PHV Town Initiative Best Practices Handbook as a reference for other local governments. These best practices were collected based on the master plans announced by each EV and PHV Town and from interviews with officials in those local governments. In January 2012, METI collected together the Best Practice Handbook II ⁽¹⁶⁾. The following are a few examples of specific initiatives undertaken by local governments. Aomori Prefecture carried out the Oirase Mountain Stream Park and EV Ride demonstration project to examine a mechanism for encouraging people to switch to EVs after the imposition of traffic restrictions on a special protection area of a national park. Nagasaki Prefecture held the Futuristic Driving Tourism demonstration project in the Goto Islands using EV rental vehicles equipped with a next-generation ITS-based navigation system. Niigata Prefecture is running a demonstration project to develop support EVs that offer a recharging service to EV drivers whose batteries have run out of charge.

2.3.2. Trends in infrastructure development and maintenance

Initiatives of national and local governments - The Green Growth Strategy set the establishment of 2 million normal charging stations by the year 2020 as a target to promote the technological development and of EVs the construction of a supporting infrastructure. As a short-term target, METI is promoting the intensive introduction of some 37,000 rapid charging stations for EVs, which is equivalent to the total number of gasoline stations in Japan, by the year 2014. Combined with normal charging stations, the total number of chargers should rise to approximately 110,000. Initiatives such as this are intended to boost the development of the necessary infrastructure to promote the spread and adoption of more EVs. METI is also implementing a promotion project of charging infrastructure for next-generation vehicles. This is an incentive system that makes the installation and construction costs of rapid and normal chargers eligible for financial assistance. The chargers will be classified as high- or normal-function types with electricity storage, billing, vehicle-to-house (V2H) functions, and the like. More generous aid is provided for the high function-type chargers. In the future, it is predicted that the establishment and maintenance of high-function charging facilities equipped with electricity storage, charging current control, billing and authentication, and V2H functions will become more active due to businesses that

will promote the development of infrastructure for next-generation vehicles.

Local governments are also establishing incentives to develop charging infrastructure. For example, Kanagawa Prefecture is undertaking various initiatives to support the development of infrastructure and promote the spread of EVs by setting a target of 3,000 EVs and 100 rapid-charging facilities within the prefecture by 2014. As a result, the target for the number of rapid-charging facilities was achieved in October of 2011 and the number of EVs exceeded 3,000 vehicles by the end of June 2012. This puts Kanagawa Prefecture in the top class for the adoption of EVs in Japan ⁽¹⁷⁾.

The previous section explained how initiatives to develop and expand the charging infrastructure for EVs are being promoted at both the national and local levels. In the future the spread of EVs will likely begin to accelerate due to the increasing number of charging facilities and the ability to compensate for the limitations of the EV cruising range.

Initiatives of private companies – A limited liability company called the Charging Network Development Organization was established through the investment of 9 companies, including Chubu Power Co., Ltd., Toyota Motor Co., Ltd., Honda Motor Co., Ltd., and Mitsubishi Motors Co., Ltd. The purpose of this organization is to expand the adoption of EVs by promoting the development of charging facilities. The organization began providing rapid charging service to registered members in April 2012. EV users who become members can make use of any of the charging facilities in the network and a portion of the dues paid by the members are passed on to the party that set up the charger, thereby reducing some of the economic burden of establishing the infrastructure. The Charging Network Development Organization has partnered with convenience stores, vehicle dealers, highways, and lodging facilities in an effort to create a virtuous cycle to promote the expansion of charging infrastructure and advance the spread and adoption of EVs ⁽¹⁸⁾.

Japan Charge Network Co., Ltd. was also established as a similar company to provide charging services for EV users. This company is sponsored by Nissan Motor Co., Ltd., Sumitomo Corporation, NEC Corporation, and Showa Shell Sekiyu K.K. Its billing service started full-scale operation in October 2012. The company has constructed a network of partnerships with convenience

stores and family-oriented restaurant chains mainly centered in the Kanto region around Kanagawa and Tokyo. The aim of this company is to expand rapid charging facilities to 4,000 locations around the country by the year 2020 ⁽¹⁹⁾.

2.4. Trends in standardization

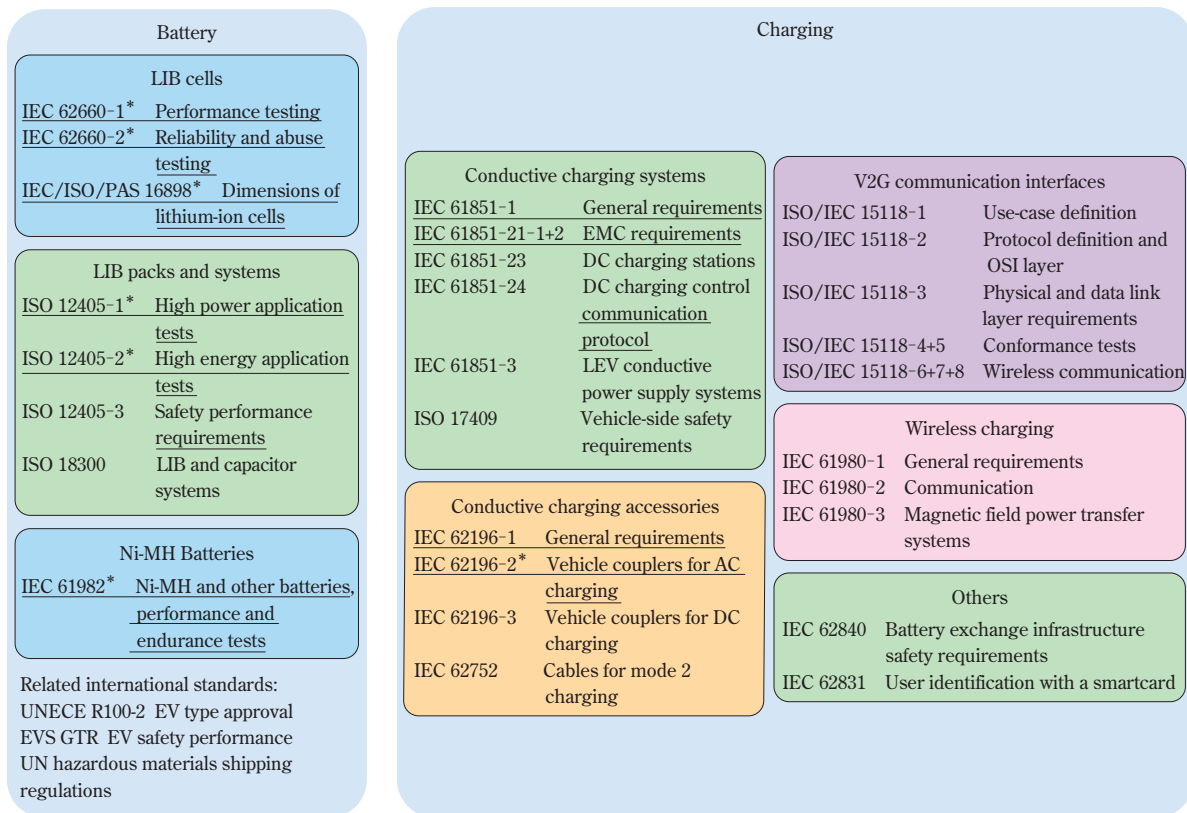
The Japan Automobile Research Institute (JARI) undertakes activities such as the standardization of technologies and components related to EVs. Fig. 4 shows the composition of the main international standards and draft standards that currently concern EV batteries and battery charging

As a part of its initiatives concerning batteries and chargers, Japan proposed performance tests for lithium-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. Germany proposed test methods for lithium-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. In addition, a publicly available specification (PAS) was issued for the dimensions of lithium-ion battery cells (IEC/ISO PAS 16898) in December 2012 based on new proposals from both Japan and Germany.

Lithium-ion batteries are subject to UN regulations when shipped via aircraft or marine vessels. Since some batteries would require excessive testing if these regulations were applied to the large lithium-ion batteries used in vehicles, activities are being carried out to rationalize the shipping regulations for large lithium-ion batteries used in EVs.

Furthermore, the following topics related to EV batteries and charging are also all under discussion: DC charging stations, digital communication for DC charging control, couplers for DC charging of vehicles, general requirements for conductive charging systems, vehicle-to-grid (V2G) communication interfaces, general requirements for wireless power supply systems, and the like.

The content of the testing that will be necessary for the standardization of high-performance batteries for next-generation vehicles is also now being considered and examined.



(Note) Standards marked with an asterisk (*) have already been issued and standards that are underlined have revisions that are still under discussion.

Fig. 4 International Standards and Draft Standards for Batteries and Charging

3 Fuel Cell Electric Vehicles

3.1. Introduction

FCVs use hydrogen as fuel and, similarly to EVs, do not emit any CO₂ when driven. This is why FCVs are also considered as a potential next-generation vehicle to help resolve environmental problems. The cruising distance of EVs can be increased by increasing the amount of batteries on board the vehicle. In the case of FCVs, cruising range is increased by increasing the amount of hydrogen fuel on board the vehicle. The rate of cost increase is lower for FCVs than EVs when increasing the cruising range in this manner. The amount of time needed to supply fuel to a FCV is the same as for an internal combustion vehicle (ICV), while it may take approximately 30 minutes or more for a rapid charge of the battery in an EV. This level of convenience and familiarity is certainly one of the strong points of a FCV, since the way that users will interact with a FCV is not that different from a conventional ICV.

However, there are still many issues related to development and the establishment of a hydrogen fuel infra-

structure that are standing in the way of the greater adoption of FCVs. Since the largest of these remaining issues is cost, automakers and other related organizations are undertaking various cost reduction measures. The following sections introduce the main trends in FCV development and hydrogen fuel infrastructure that occurred in 2012.

3.2. Trends in FCV development

Many reports have described the progress of technological developments to solve the performance-related issues of FCV, such as cruising range, vehicle efficiency, low-temperature starting ability, refueling time (hydrogen replenishing time), and the like. There has been remarkable progress made toward the actual adoption and spread of FCVs from 2015.

Fig. 5 and Fig. 6 show the breakdown of the various costs of an FCV fuel cell (FC) system. These figures clearly indicate that reducing the cost of both the stack itself and the surrounding auxiliary components is quite important⁽²⁰⁾. Consequently, measures are being taken to simplify the FC system and to reduce the cost of the materials used in the stack, among others.

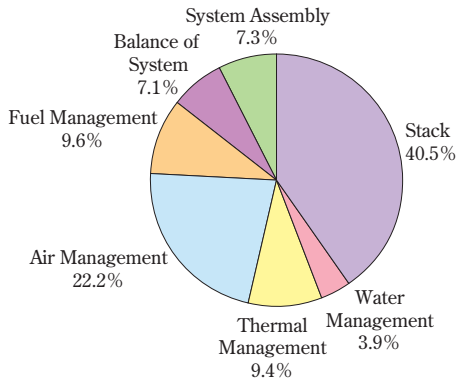


Fig. 5 Breakdown of FCV system costs⁽²⁰⁾

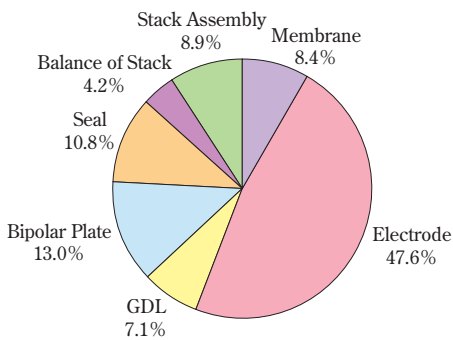


Fig. 6 Breakdown of FCV stack costs⁽²⁰⁾

Managing or controlling the internal temperature and humidity of the stack is necessary to properly maintain the power generation conditions of the stack. Therefore, the FC system is composed of multiple sub-systems, such as the humidification system, cooling system, and gas supply system, that all work together in a single system.

Simplifying and reducing the number of these sub-systems, as well as other measures to make use of existing mass-production parts, will be necessary to reduce the cost of the FC system. In the case of the humidification system, the water produced via power generation needs to be used efficiently within the stack, and a battery needs to be developed that can produce power even under low humidity. If these challenges can be overcome, then the humidifying function from outside of the stack can be reduced, the size of the humidifier module can be decreased, and further reduction also becomes possible. The same parts used in the cooling system of an ICV may be used in the FCV cooling system, and less expensive, mass-produced parts such as the motor and inverter of existing hybrid systems may be used in the FCV drivetrain. The cost of the FCV system can be reduced if these kinds of common parts can be utilized⁽²¹⁾. The



Fig. 7 FC stack of Nissan Motor Co., Ltd.⁽²¹⁾

largest contributor to the cost of the fuel supply system is the tanks that store the hydrogen in the vehicle. The majority of FCVs are equipped with high-pressure tanks that store the hydrogen at a pressure of 70 MPa. These tanks have a high energy density, but the best way to reduce the manufacturing cost of these tanks is an issue. The majority of this cost is due to the materials. Therefore, it may be possible to reduce the cost of storing the hydrogen on-board the vehicle by developing a lower cost, general-purpose grade CFRP to replace the current CFRP, improving the manufacturing method by optimizing the laminated structure to reduce the amount of CFRP used, and reducing the number of tanks equipped on the vehicle.

After analyzing the breakdown of the cost of the stack, reducing the material cost of the FC membrane-electrode assembly (MEA) is clearly necessary. Consequently, a material design that reduces the amount of platinum catalyst in the electrodes and efficiently uses a small amount of platinum, as well as the development of alternative catalysts is being promoted.

Developing a stack with a high power density will lead to a reduction in the size of the stack and also help to reduce material costs. Nissan Motor Co., Ltd. has developed its third-generation stack (Fig. 7) that greatly improves on the first-generation stack (2005) by reducing volume by one-half, reducing the amount of platinum used by one-quarter, and reducing the different types of parts by one-quarter to ultimately bring the cost down to one-sixth of the original⁽²²⁾. In 2012, Nissan also announced the TeRRA concept (Fig. 8) that is equipped with this new stack⁽²²⁾.

Toyota Motor Co., Ltd. also developed a new stack that achieves a power density of 3 kW/L, which is more than twice that used in the 2008 FCHV-adv⁽²³⁾. In addition,



Fig. 8 TeRRRA by Nissan Motor Co., Ltd.⁽²²⁾



Fig. 9 FCV-R concept by Toyota Motor Co., Ltd.⁽²³⁾

tion, in the FCV-R concept (Fig. 9) that was announced in 2011⁽²⁴⁾, the size of the FC system was reduced and placed under the floor of the vehicle to help ensure lower cost and more trunk space. Work is continuing on the development of technologies to further reduce the cost of a FCV to 1/20 of the cost of the FCHV-adv before the initial release timing in 2015.

In the wake of the Great East Japan Earthquake, there are rising expectations that EVs and FCVs can provide new functions that were previously unavailable, such as supplying electrical power during a disaster. Since the length of the cruising range of FCVs is connected to the strength of the power supply function, it is being examined whether a FCV could be used as a power supply source for a standard home in an emergency. Honda Motor Co., Ltd. is developing an external power supply function for the FCX Clarity FCV that would allow the vehicle to supply a maximum of 9 kW of electrical power to a standard home for approximately 6 days. In addition, Honda also installed the first solar hydrogen station in Japan on the grounds of the Saitama Prefectural Office in March of 2012 (Fig. 10). This station uses an original high-pressure water electrolysis system to manufacture and then compress the hydrogen. Honda is using this system to verify the reduction of CO₂ emissions in an ac-



Fig. 10 Solar hydrogen station and FCX Clarity by Honda Motor Co., Ltd.⁽²⁵⁾

tual urban environment⁽²⁵⁾.

3.3. Hydrogen infrastructure and review of regulations and standards

2015 is to be the year that FCVs are initially introduced into the Japanese market. In preparation for this, 13 private companies from the energy, automotive, and other fields have come together to promote a plan to establish hydrogen stations in approximately 100 locations in four major metropolitan areas: Tokyo, Chukyo, Kansai, and Kitakyushu⁽²⁶⁾. The Japanese government is also preparing for the introduction of FCVs and hydrogen stations by promoting the establishment of compressed hydrogen filling facilities at gasoline stations to help reduce the cost of building and operating hydrogen stations. In addition, the government is also promoting the review and reform of regulations that concern the handling of hydrogen. In June 2012, JX Nippon Oil and Energy Corporation announced that it would begin operating the first service stations in Japan with both gasoline pumps and hydrogen filling machines by around February of 2013 as a proving test of the new technology. These service stations will initially be in two locations in Kanagawa Prefecture and Aichi Prefecture. This proving test is being carried out as part of joint research being undertaken by the New Energy and Industrial Technology Development Organization (NEDO) and the Research Association of Hydrogen Supply and Utilization Technology (HySUT). In the future this research is expected to lead to decreases in the cost of constructing new hydrogen stations.

Since the cost of hydrogen will have an impact on the spread and popularity of FCVs, initiatives to reduce the cost of hydrogen will be necessary. At the same time, it will be equally important to ensure a constant level of

quality. In other words, appropriate hydrogen fuel specifications are also important to protect the stack. Japan is the current chair of ISO/TC197 WG 12 (hydrogen fuel specifications) and discussions about the allowable concentration of impurities in hydrogen fuel for FCVs are currently ongoing. An international standard, ISO 14687-2 (Hydrogen fuel – Product specification – Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles), concerning the hydrogen fuel specifications for FCV was issued on December 1, 2012.

3. 4. Conclusions

The problems posed by the high costs of development and manufacturing FCVs will need to be solved to promote the spread and adoption of FCVs. It will also be necessary to build and maintain the required infrastructure on a global scale. There has been good cooperation and working partnerships between different automakers to develop hybrid and other environmentally friendly technologies. Therefore, it is possible that these partnerships will continue as these same companies enter the FCV field. It is thought that the huge burden associated with independent development will lead to more technical cooperation and partnerships to help hold down the investment costs of technological development and create economies of scale so that manufacturing costs will

also continue to decline.

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