

DEVELOPMENT POTENTIAL OF HYDROGEN FUEL CELL ELECTRIC VEHICLES IN CHINA

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Summary

- China aims to become a powerful automobile country centering on new energy vehicles. The country has begun putting full effort into the development and spread of fuel cell electric vehicles (FCEVs) as a field that follows battery electric vehicles (BEVs). China first aims to form an early-stage FCEV market for commercial fleet such as buses and trucks, and then to roll it out to the personal passenger car market in the future.
- There is still a large gap between Chinese and international technologies in the core components of fuel cells and hydrogen storage system. The technology transfer desired by China will possibly bring foreign companies business opportunities to add its value onto the domestic manufacturing ecosystems. Though some may concern about intellectual property protection and information leakage risk, it should be important for foreign companies to see the potential of the market in China, and consider the right time to enter this market not to miss the opportunities as China also accelerates its own technology development.

CHINA'S FUEL CELL POLICY - TO BECOME THE WORLD LEADER OF AUTOMOBILE INDUSTRY WITH NEW ENERGY VEHICLES

The automobile production in China has been ranked first in the world since 2009 and even steadily increased. In 2018, it reached 27.81 million and accounts for about 30% of the global production. In the “Made in China 2025” the Government of China released in 2015, it set the goal to become the top level automobile country in the world within 10 years. To this end, China focuses on new energy vehicles (hereafter “NEVs”). While it has been difficult for the country to catch up with the global established industry in internal combustion engine (ICE) technologies, China intends to take the leadership and climb to the top with NEV industry because it looks relatively new and China has its strength in the key component, battery. In the “Medium- and Long-Term Development Plan for the Automobile Industry” compiled in May 2017, China expects the domestic automobile market in 2020 to be 30 million, and 2 million of which will be NEVs. By 2025, the market is assumed to grow up to 35 million and about 20% of which, or 7 million are NEVs.

NEVs in China indicate all the electric vehicles (EVs) but hybrid vehicles (HEVs) that are fueled only with gasoline fuels: namely plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs) (Fig. 1).

80% of the domestic NEV market in China accounts for BEVs with growing sales of small cars, to be sure. Still, the driving range of BEVs is rather short since battery capacity is restricted by the limitation of weight and space of car body. In addition, some point out that the prices of BEVs will not decline as expected in the future from the perspective of material procurement for batteries. FCEVs, on the other hand, are powered by fuel cell (FC)

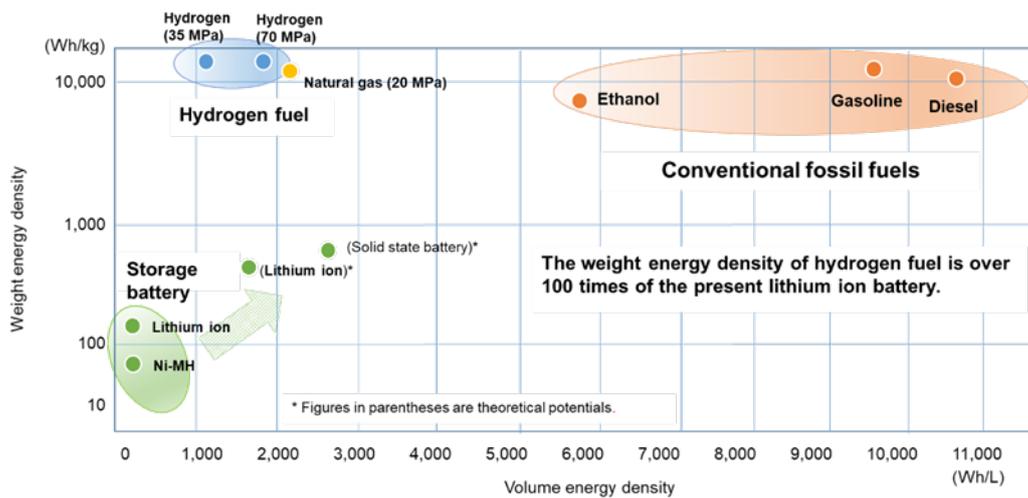
Fig. 1: Comparison of Electric Vehicles(xEV)

	China's "New Energy Vehicles"				
	Hybrid electric vehicle (HEV)	Plug-in hybrid electric vehicle (PHEV)	Battery electric vehicle (BEV)	Fuel cell electric vehicle (FCEV) Range extender system	Fuel cell electric vehicle (FCEV)
Powertrain system					
Driving device	Engine + motor	Engine + motor	Motor	Motor	Motor
Fuel	Gasoline	Gasoline, Electricity	Electricity	Hydrogen	Hydrogen
CO ₂ emissions	Yes	Yes	No	No	No

Source: MGSSI based on various materials

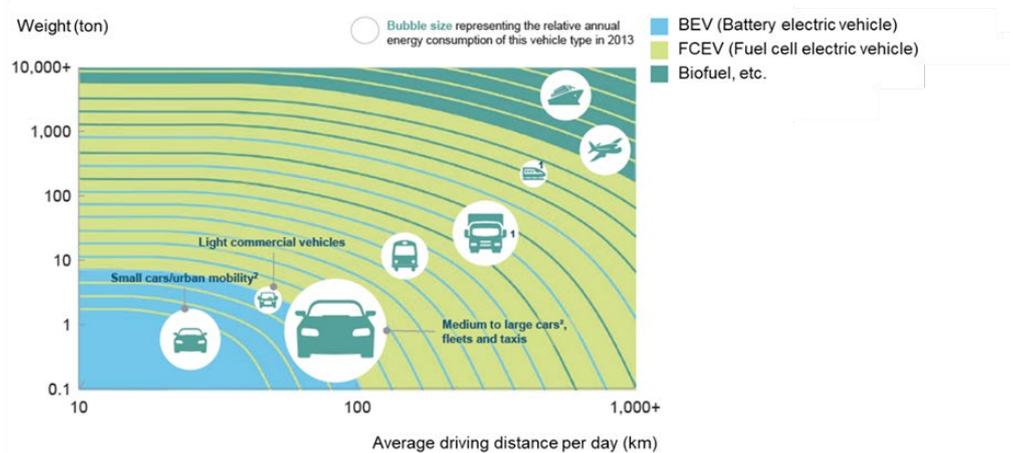
which generates electricity from hydrogen fuel. Since hydrogen has high power density more than hundreds folds of that of batteries, more fuel, or energy, can be on board compared to BEVs (Fig. 2), which can be advantage in decarbonizing vehicles of middle- and large-duty and/or for long-distance transport. Indeed, the driving range of FCEV is comparable to that of conventional vehicles with ICE and it takes only three minutes for refueling at earliest. For these reasons, FCEVs are expected to play an important role just as well as BEVs and the other EVs, being complement each other in low-carbon mobility (Fig. 3).

Fig. 2: Energy density comparison



Source: MGSSI based on various materials

Fig. 3: Projected economic attractiveness of lower-carbon mobility by weight/driving distance

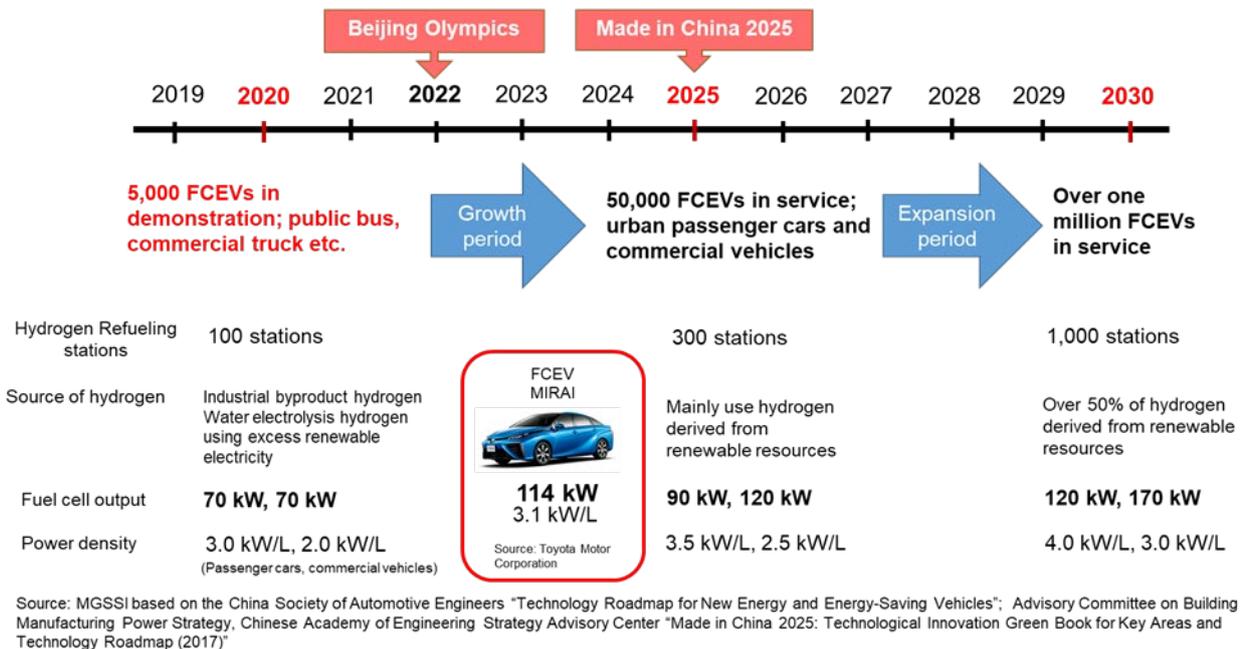


1 Battery-hydrogen hybrid to ensure sufficient power
 2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A-/B-segment cars and a 50% lower energy demand
 Source: Toyota, Hyundai, Daimler

Source: Hydrogen Council "How hydrogen empowers the energy transition"
<http://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf>

At the end of 2015, Toyota Motor Corporation launched the world’s first mass-produced FCEV “MIRAI” into the market. The FCEV market is at an early stage of development, mainly led by automobile companies in Japan, South Korea, Europe, and the United States. The mass production at full scale will be established by around 2020. Ambitious to be the world leader of automobile industry with its NEV production, China positioned FCEVs as a priority area following BEVs. Hydrogen and FCs are described as a new strategic industry in the “13th Five-Year Plan on Energy Technology Innovation” which was released in 2016. In the same year, the China Society of Automotive Engineers developed the “Technology Roadmap for New Energy and Energy-Saving Vehicles” directed by the Ministry of Industry and Information Technology, and two years later “Made in China 2025: Technological Innovation Green Book for Key Areas and Technology Roadmap (2017).” was issued. In these documents, China set the aggressive goals of producing 5,000 FCEVs in 2020, 50,000 units in 2025, and 1 million units in 2030 (Fig. 4).

Fig. 4: FCEV technology roadmap towards 2030



EARLY MARKET OF FCEV IN CHINA - GETTING OFF TO A FLYING START

It is notable that China clearly focuses on buses and delivery cars (trucks and vans) as the early market of FCEVs. Since such commercial vehicles travel longer distances a day than personal passenger cars, most BEVs in the present market of China are not likely to meet the requirement of driving range. In addition, fuel consumption for commercial vehicles running on regular routes is predictable, which makes it easier to locate refueling stations and operate them with some certainty of sales. It can help the operators with economic feasibility too. The attempt to concentrate on commercial FCEVs as the first market looks even strategic after seeing the first adopting countries of passenger FCEVs, which all have been struggling with the shortage of hydrogen refueling stations.

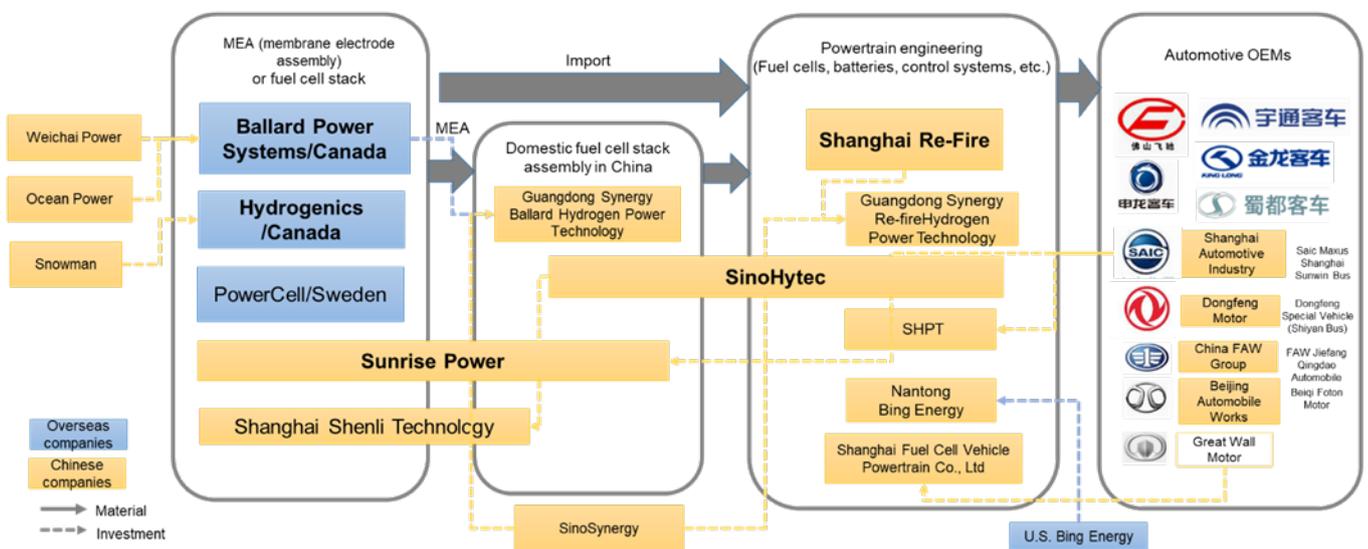
It was only two years after the roadmap release that the annual sales of FCEVs in China reached 1,527 units in 2018, and total sales so far is 3,428 units. With unfilled orders included, China is highly likely to achieve the goal of selling 5,000 units in 2020. Certainly there are some price ranges depending on the categories, but if assuming that all of them are middle-sized FCEV buses which cost 3 million CNY each (48 million JPY; at 1 CNY=16 JPY), the sales of FCEVs would have already created 160 billion JPY market.

The biggest contributor to jump start is the generous subsidies from the government. The upper limit of subsidies for PHEV and BEV, both of which are going through an expansion period, reduced to 180,000 RMB (2.88 million

JPY) for bus and 100,000 RMB (1.6 million JPY) for truck, respectively. Yet the subsidy of up to 500,000 CNY (8 million JPY) are given to FCEVs. Another encouragement for logistics companies to purchase FCEVs is the regulation which bans diesel delivery cars to enter some cities. Furthermore, another regulation in some provinces forces logistics industry to switch all the vehicles to NEVs after a certain period (or depreciation). The approach of intensively stimulating consumer demand with a carrot (subsidies) and stick (regulations), which is sometimes seen in China's strategy, looks working well.

The quick response of manufacturers is also the key factor to meet the rapid increase in an early market. As of the end of 2018, a total of 77 FCEV models for buses and delivery cars of 17 companies are eligible for the NEV subsidy. The primary reason why so many FCEV models have been designed in such a short time is the outsourcing of FC system engineering. Different from Japanese automobile companies that develop whole FC systems by themselves independently, Chinese automobile OEMs tend to outsource the powertrain engineering including FC technology (Fig. 5). Sharing the same engineering company among automobile OEMs makes them utilize the common platform and develop new models in a shorter time so that even OEMs without having their own technologies could launch FCEV models, which let more OEMs enter the market in China.

Fig. 5: Typical value chains for FCEV production in China



Source: MGSSI

Another reason that shortens the development period is the range extender system which includes FC as auxiliary power unit which generates electricity to charge battery (Fig. 1). When FC is the main power source which drives motor directly, like FCEVs produced by Japanese automobile companies, all the equipment including pump and compressor as well as FC stack require the most advanced technology and precise control. The range extender FCEVs, on the other hand, do not require those high levels of performance for each equipment or control, which also lowers the barriers to market entry.

Certainly, having both battery and FC is not the perfect system when considering the overlapping functions and weight. In a long term China aims to develop FC system which can work as primary drive power. However, given the priority to let the new market grow up in the shortest time, the strategy to spread range extender FCEVs in commercial vehicles with relatively eased vehicle body constraints would be effective.

THE SPREAD OF HYDROGEN REFUELING STATIONS SUPPORTED BY LOCAL GOVERNMENTS

Along with the introduction of FCEVs, refueling stations are also needed. Yet, a hydrogen refueling station (HRS) is made up of very expensive equipment and logistics chain of hydrogen fuel is still challenging, which increase not only initial costs but also operation costs. This problem has been troubling smooth spread of hydrogen stations in Japan and other early adopters. In China, though they have the same problem as well, what differs from the other countries is the strong support from the local governments which have ambitious to promote new industries in their area and boost up local economy. The encouragement resulted in over 20 HRSs newly constructed in 2018.

Foshan in Guangdong Province is the city where the largest number of HRSs are constructed all over China, and whose government has been enthusiastic to establish FC industry since the early times. In Foshan (Yunfu) Industrial Transfer Park, the first FC stack factory in China was constructed under the joint venture of the international FC technology company, Ballard Power systems (Canada) and Guangdong Nation-Syenergy Hydrogen Power Technology. Domestic companies are also attracted to invest in the area. Guangdong Guangshun New Energy, on-board compressor manufacturer which has a 90% share of the domestic market, has established their base at the Nanhai district of Foshan, where auto-related industries are concentrated. In the city, seventy FCEV buses have been running on six bus routes since last December. Those buses were manufactured by a local automobile OEM, Foshan Feichi. In 2019, an additional 90 FCEV buses will be in operation. In order to fuel hydrogen into those buses, the bus-operating company also constructed a hydrogen station as its own business supported by the local government. While in Japan it is said the number of HRSs depends on the development of FCEVs and vice versa, or chicken-and-egg, in China strong incentive and regulation given by the government creates the demand of FCEVs, which brings out the needs of refueling infrastructures. Such an approach starting from stimulating the end-user should look unique in China and even effective. There are five HRSs built in Foshan until the end of 2018, and the city government intends to support further installation continuously, to reach 57 HRSs by 2030.

In order to increase the number of HRSs, installing alongside and co-operating with existing gas stations of Sinopec and PetroChina seems a promising approach. By utilizing the assets of Sinopec and PetroChina, which have a total of 50,000 gas stations throughout China, it is possible to secure land and improve operational efficiency. Moreover, byproduct hydrogen from refineries and petrochemical plants can be purchased at lower prices. Those companies and HyPower Energy Tech, a hydrogen station company based in Beijing, are going to discuss required safety code and standards for multi-fuel station in China.

When it comes to the hydrogen source, the Chinese government has drawn up a plan to use industrial byproduct hydrogen at low price in the short term and make a shift to clean hydrogen derived from renewable resources in the long term. It is estimated that the chlor-alkali industry, which produces highly pure byproduct hydrogen, has the potential to supply 368,000 tons a year, which is enough to fuel 250,000 delivery trucks each of which travels 200 kilometers a day. Furthermore, in China, large amounts of excess electricity generated from wind and solar power are abandoned. If all such electricity is converted into hydrogen, it is possible to meet the demand to charge hydrogen fuel into about 2 million personal passenger cars.

In Beijing and Zhangjiakou, Hebei Province, FCEV city buses were introduced ahead of the 2022 Winter Olympics. It is cold in winter in these cities, which is a good reason to choose FC as power source which can start up even below the freezing point. Another advantage of the area is the potential for hydrogen production using abundant electricity from wind power in Zhangjiakou. At the model hydrogen industry park in the city, a demonstration will begin in June 2019, where hydrogen will be produced through water electrolysis with equipment made in China. The electricity powering electrolysis comes through utility power grid where non-clean electricity also flows, but the power purchase contract at special tariff flexibly matched to the local wind power operation status helps the electricity regarded as clean, in an indirect sense. Another project in Guyuan

County, located next to Zhangjiakou, water electrolyzer was installed at a wind power plant and about to start its operation soon.

Some mention the abundant coal resources can be converted to hydrogen through gasification, which is necessary to mitigate carbon dioxide emission in the process. Carbon capture and storage (CCS) technology in China is just at demonstration stage and will be unknown when it is commercialized until the government decides its policy, on which close attention is being paid.

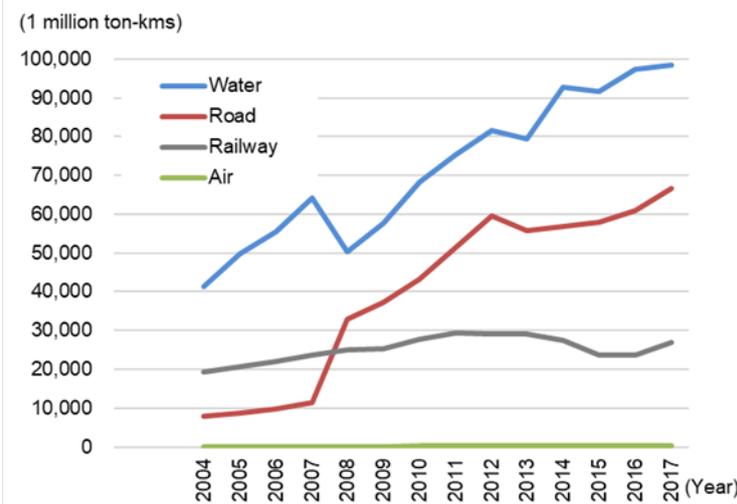
As for on-load transport of hydrogen up to HRSs, at present it is transported in cylinders in the form of compressed gas at present. In preparation for larger volume transport of hydrogen in the future, liquefied hydrogen at higher density is also being considered among the stakeholders.

BEYOND THE COMMERCIAL FLEETS – THE ULTIMATE TARGET IS THE MARKET OF PASSENGER FCEVS

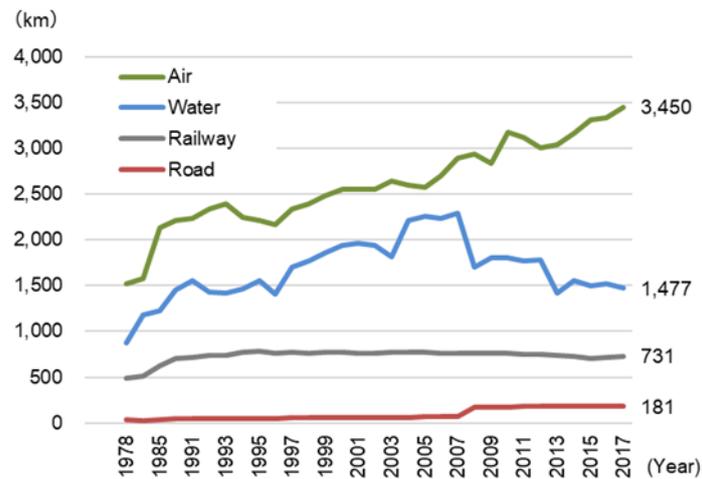
China plans to replace all city buses operating in the big cities to NEVs by 2020. FCEVs can have the advantages in the cold areas like Beijing and Zhangjiakou, and long-distance routes.

In addition, taking a look at the change in the freight transportation volume in China reveals a steady increase in road freight transportation volume, which should bring out a growing demand of trucks and other delivery cars (Fig. 6). While transportation modes are diversified thanks to the development of railways and river traffic infrastructure, the average transportation distance is about 731 kilometers for rail transportation and about 181 kilometers for road transportation. This suggests that the mode of transportation used differs according to the transportation distance (Fig. 7). Furthermore, since rail transportation has several problems in terms of punctuality, efficiency, and reliability, logistics companies and parcel delivery companies often opt for road transportation with private trucks even for long-distance. In addition, e-commerce including mail order is growing rapidly in China, and it is becoming widespread not only in large coastal cities but also in inland cities such as Chongqing and Sichuan Province along with economic growth and increase of the middle-income. It is estimated that e-commerce shipping will account for about 30% of all retail sales by 2022, and the demand for road transportation is expected to continue to grow going forward.

Fig. 6 Freight Ton-Kilometers by mode of transport



Source: China Statistics Yearbooks

Fig.7 Average transport distance of freight in China

Source: China Statistics Yearbooks

Noticing growing logistics demand and environmental regulations, some logistics companies are quick to introduce NEVs. Shanghai Sinotran New Energy Automobile Operation (STNE) is a Shanghai-based venture company established in 2017 with the aim of establishing clean urban logistics using hydrogen energy. The company purchased 500 FCEV trucks in 2018 (Fig. 8) and leases them to the EC giant JD.com, the new kind of supermarket under Alibaba Hema Fresh, furniture retailer IKEA, and other companies for intercity parcel delivery. In order to power its own trucks, STNE launched HRS business whose first station is in operation. At the station over one ton of hydrogen is fueled a day, which is the world's largest volume for a HRS. Yet, the present capacity is not enough to operate all 500 trucks and the company has signed a contract to purchase an additional 1,000 FCEV trucks in 2019. For these, STNE has already started constructing several HRSs and even plans to have nine or ten more in Shanghai and surrounding cities by 2021. Those project are in partnership with Sinopec, ChinaPetro, and Shenergy Group, a major energy company based in Shanghai. Receiving many inquiries from EC commerce companies and other clients, STNE thinks of extending its distribution network to the Yangtze Delta at the next stage. In the future even intercity transportation covering 500- to 600-kilometer distances and logistics services in other regions is possibly being considered.

Fig. 8: FCEV truck operated by STNE

Source: Photo taken by the author

Along with the growing demand for commercial NEVs, the central government of China encourages domestic parties to accelerate the development of FCEV technologies, with a view towards the passenger FCEV market beyond it. China aims to grow FCEV industry following the thrived BEV one, strengthening domestic FC technologies, and at the end to become the world's top player covering the whole economy of hydrogen and FCs.

Shanghai is one of the first cities that have responded to the central government's policy. In September 2017 the city released the Shanghai fuel cell vehicle development plan, which shows a roadmap to implement test operations of 3,000-level FCEV buses and delivery cars by 2020 and then expand the usage of FCEVs to increase the number of passenger FCEVs to over 20,000 units by 2025. In February 2018, Shanghai city opened

the hydrogen energy and fuel cell industrial park in the Jiading district, where Tongji University and Shanghai Automotive Industry Corporation locate in. Those entities have led domestic research on FCs for many years. The target of the park is to attract relevant companies and create a supply chain with production worth 10 billion yuan (160 billion yen) by 2025.

The Nanhai district of Foshan also put effort into not only introducing overseas FC technologies but also establishing and developing domestic manufactures. Guangdong Telos Auto Power Systems, the FC system subsidiary established by Guangdong Guangshun New Energy, is one of the major companies in the Xianhu Hydrogen Valley, a special economic zone for relevant industries.

WHAT FOREIGN COMPANIES ARE EXPECTED – THE INTERNATIONAL COOPERATION TO GROW UP THE FCEV INDUSTRY TOGETHER

The ultimate goal of China is to become one of the world leaders in automobile industry. On the way towards it, the country aims to strengthen domestic FC technologies and develop its value chain. The advanced FC technologies are encouraged to be brought in and transferred to domestic companies through joint-venture and co-operation not only in production but also in R&D activities.

Core technologies that determine the electricity output of an FC include: (1) components such as membrane electrode assembly (MEA) and conductive plates; (2) gas-related auxiliary equipment such as compressors; and (3) their control systems. In these technologies, there are large gaps between Chinese and foreign manufacturers. When compared in terms of output density, a major performance indicator of an FC stack, Toyota's world's first mass-produced FCEV MIRAI has an output density of 3.1 kW/L, while an FCEV made using current Chinese technologies is said to have an output density of about 2.0 kW/L. In order to use FC stacks for compact passenger cars, it is necessary to further increase the output density.

There are large gaps in on-board hydrogen storage system as well. The latest technology for 70-MPa high-pressure hydrogen storage on passenger FCEVs is carbon fiber composite cylinder with plastic inner liner. Still in China metallic inner liner is used for a lack of the advanced technology, which is under development in demand for lighter cylinder with strength. To accelerate its commercialization, technological transfer from foreign companies is desired. But when it comes to joint development with Chinese companies, not a few foreign companies are, from past experience, concerned about damage caused by the violation of intellectual property and outflow of technologies.

However, China is also strongly pushing domestic R&D to reach the global top level, as "Technology Roadmap for New Energy and Energy-Saving Vehicles" shows the performance of its FC system in 2020 is to be equivalent to those of the latest MIRAI, and even higher in 2025. Considering this acceleration in China as well as the potential market to thrive for the future, European, American and South Korean FC technology-related companies have already started establishing relations with Chinese companies through joint technological development, capital tie-up, participation in funds, etc. (Fig. 5).

When establishing joint ventures with Chinese companies, it is often found that unique practices in Chinese business, the language barrier, as well as significance of political decisions let the foreign companies recognize the importance of local partners. The companies entering into China need to find the best partners for each other, networking and mutually understanding with the Chinese stakeholders, which requires in-depth understanding of the entire value chain throughout hydrogen FC-related industry.