Series "Ushering in a New Era of Carbon Neutrality" (9)

Advancing Electrification in the Transportation Sector

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Electric-powered vehicles are an effective means of decarbonization

It would not be possible to transport goods and people to all corners of society without any automobiles. On the other hand, it is difficult to capture the carbon dioxide (CO_2) that is emitted by automobiles, and this poses a challenge for the decarbonization of the transportation sector. This is one of the reasons behind the advancing electrification of automobiles around the world.

As of 2018, the CO_2 emissions volume of Japan's transportation sector made up about 18.5% of Japan's total emissions, while CO_2 emissions from automobiles made up 15.9% of Japan's total emissions. Japan, following suit with global trends, is also pursuing the policy of promoting electrification in the transportation sector. In 2020, the Government of Japan announced that the sale of new gasoline-powered vehicles will be prohibited by the mid-2030s, and only the sale of electric-powered vehicles will be permitted.

Characteristics of internal-combustion vehicles and electric-powered vehicles

Automobiles can be classified as internal-combustion vehicles and electric-powered vehicles (Figure), based on their drive systems. Internal-combustion vehicles can be broadly categorized as gasoline vehicles and diesel vehicles; the former is fueled by gasoline, while the latter is fueled by light oil (diesel fuel). Electric-powered vehicles are automobiles that are fully or partially driven by an electric motor; specifically, they include battery-powered electric vehicles, fuel-cell vehicles, and hybrid vehicles. The CO_2 emissions of automobiles can be grasped and understood through the concepts of "well-to-wheel" (WtoW) (the processes starting from the primary energy source that can be obtained from nature without any conversion or processing, to the actual driving of the vehicle), and "tank-to-wheel" (TtoW) (the processes starting from the storage battery or fuel tank, to the actual driving of the vehicle). Internal-combustion vehicles that use fossil fuels emit CO_2 in both the WtoW and the TtoW processes. On the other hand, liquid fuel such as gasoline and light oil generates high energy output per both unit mass and volume, and is characterized by the fact that it can be replenished in just a few minutes.

	Internal-combustion vehicles	Electric-powered vehicles

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This paper is an authorized reprint of the original paper published in the June 15, 2021 issue of Financial Affairs (Kinzai Weekly).

	Gasoline vehicles	Diesel vehicles	Battery-powered electric vehicles	Fuel-cell vehicles	Hybrid vehicles
TtoW CO_2 emissions	-	Somewhat superior	Superior (No emissions)	Superior (No emissions)	Somewhat superior
WtoW CO_2 emissions	-	Similar	Somewhat inferior – Superior	Somewhat inferior – Superior	Somewhat superior
Cruising distance	-	Somewhat superior	Similar	Similar	Somewhat superior
Speed of energy replenishment	About 5 minutes	About 5 minutes	30 minutes – 10+ hours	About 5 minutes	About 5 minutes
Characteristics	-	Strong torque, essential for buses, trucks, etc.	Vehicle weight increases if cruising distance is extended	Difficult to take advantage of the cruising distance merits for small vehicles	There are various formats in aspects such as storage battery capacity, motor output, etc.

Source: Prepared by the author based on the specifications of vehicles that are commercially available as of 2021

On the other hand, there are multiple types of electric-powered vehicles. Other than hybrid vehicles, vehicles that are powered only by electricity generate zero TtoW CO_2 emissions, and do not produce any emission gases. However, WtoW CO_2 emissions volume is dependent on factors such as the power generation method for the electricity used for charging, and the production method of hydrogen.

The simplest system for electric-powered vehicles belongs to the battery-powered electric vehicle. Its driving energy is supplied by an in-vehicle storage battery. However, the energy density of current storage batteries in 2021 is lower than that of liquid fossil fuels, and many electric vehicles have a shorter cruising distance (the distance it can continue driving for without recharging) than internal-combustion vehicles of a similar size. Furthermore, as charging speed is generally determined by “Size of charging current × Size of charging voltage × Charging time,” it would take several hours to charge a car at 100V or 200V, which is the usual voltage available at domestic homes. Therefore, large electric currents and high voltages are necessary for rapid charging.

Fuel-cell vehicles compensate for these issues through the use of hydrogen and fuel cells. The amount of energy generated per kilogram of hydrogen is about 2.7 times that of gasoline, and the cruising distance per kilogram of fuel is about four times that of the actual fuel consumption of gasoline vehicles (converted as 20 km/liter). However, the amount of energy generated per unit volume of compressed hydrogen is about one-tenth that of gasoline. Moreover, hydrogen tanks come in large cylindrical shapes such as propane gas cylinders, and therefore cannot be efficiently mounted in vehicles. For such reasons, it is difficult to secure cruising distance in small vehicles. As hydrogen, which is the fuel, can be made from renewable electricity sources and water, it is relatively easy to achieve near-zero WtoW CO_2 emissions. However, it faces challenges such as the loss of approximately 40% of the energy from the point when hydrogen is produced from electricity, and the widespread development of hydrogen supply infrastructure.

Hybrid vehicles are electric vehicles mounted with internal-combustion engines, and fuel economy is improved by using motor drive to cover the driving ranges that the internal-combustion engine is inefficient at. In addition, electricity is generated through the regenerative brake, which uses the motor as a power generator when decelerating; this makes it possible to reuse a part of the vehicle's kinetic energy, which is conventionally discarded as heat, to drive the vehicle. There are various types of hybrid vehicles, including "series hybrid vehicles" that use the engine exclusively for power generation, "parallel hybrid vehicles" that use the motor as an auxiliary driving device for the engine, as well as "power-split hybrid vehicles" that enable the changing of the roles of the motor and engine at will. There are also "plug-in hybrid vehicles," which have in-vehicle batteries that can be charged directly.

The need for public-private partnership

In order to realize a zero-emission society through the electrification of automobiles, it is necessary to reduce WtoW CO_2 emissions, as well as decarbonize the primary energy source that is at the upstream of the supply-chain. For battery-powered electric vehicles, the power source can be changed from thermal power energy, which burns fossil fuels, to renewable energy or nuclear energy. As for fuel-cell vehicles, the primary energy source of hydrogen can be changed from fossil fuels to renewable energy, and capture and storage facilities for CO_2 can be installed in hydrogen production plants that use fossil fuels. Even for internal-combustion vehicles, the adoption of carbon-neutral fuels, such as biofuels, makes it possible to substantially reduce WtoW CO_2 emissions volume.

These measures cannot be fully achieved by the automobile industry alone. There is a need to put in place cross-industry initiatives in areas including the decarbonization of the power supply configuration, and the development of supply-chains to supply hydrogen and carbon-neutral fuels.

To realize decarbonization, it is necessary to develop and popularize vehicles with excellent economic rationality and convenience, while taking into consideration how the vehicles are used. For example, it is difficult to replace vehicles with long cruising distance per trip (such as express buses and large trucks that are responsible for long distance transportation) with battery-powered electric vehicles that take a long time to charge. If the society is to achieve decarbonization as a whole, it is also important to enhance the convenience of electric-powered vehicles through means such as enhancing power generation capacity, developing the power transmission and distribution networks, and expanding charging and hydrogen supply infrastructure.

If Japan aims to continue acquiring foreign currencies through the export of automobiles in the future, it is important to secure the raw material resources such as storage batteries and motors, and to establish supply networks for electric devices (storage batteries, semiconductors, motors, etc.) that return profits to Japan and create employment. In order for Japan to continue creating the world's best automobiles, there is a need for public-private partnership in areas such as the formulation of a national resource strategy and industry policies, and regulatory reform for the automobile sector.

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