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The transportation sector is responsible for around 20 percent of all carbon dioxide (CO_2) emissions in Japan. Of this amount, vehicles are responsible for producing a very high 90 percent. While CO_2 emissions from trucks have been falling, emissions from passenger cars have increased considerably by around 45 percent over the base year (fiscal 1990). To reduce CO_2 emissions from the transport sector, therefore, it is imperative that we reduce such emissions from passenger cars.

There are four approaches to reducing CO_2 emissions from passenger cars, namely, (1) reducing the demand for travel, (2) switching to low-emission means of transport, (3) reducing CO_2 emissions from cars that are already on the road and (4) reducing CO_2 emissions from new cars (improved fuel economy). To realize Item (3), the application of eco-driving and the use of biofuels have been promoted, while for Item (4), electrification of the powertrain (engine and transmission), i.e., electric drive vehicles, is attracting attention.

Electric drive vehicles can be broadly divided into three types depending on the degree of electrification. Specifically, they are hybrid electric vehicles (HEVs), plug-in HEVs (PHEVs) and electric vehicles (EVs). In particular, EVs, which produce zero CO_2 emissions on the road, have become the focus of attention over the last one to two years. However, the high price of such vehicles (especially the expensive rechargeable batteries) as well as problems such as the lack of a well-developed charging infrastructure means that HEVs will most likely become the mainstream of electric drive vehicles over the next ten years.

As a means of reducing CO_2 emissions in the transportation sector, it is probably unreasonable to expect too much of EVs. Nevertheless, with innovation in terms of technologies and business models, there is a good chance that the market for EVs will expand. If, for example, the application of new business models such as the reuse of used EV batteries and EV car sharing can result in a drop in the price of EVs, the market for EVs would expand, making a significant contribution to reducing CO_2 emissions from passenger cars.

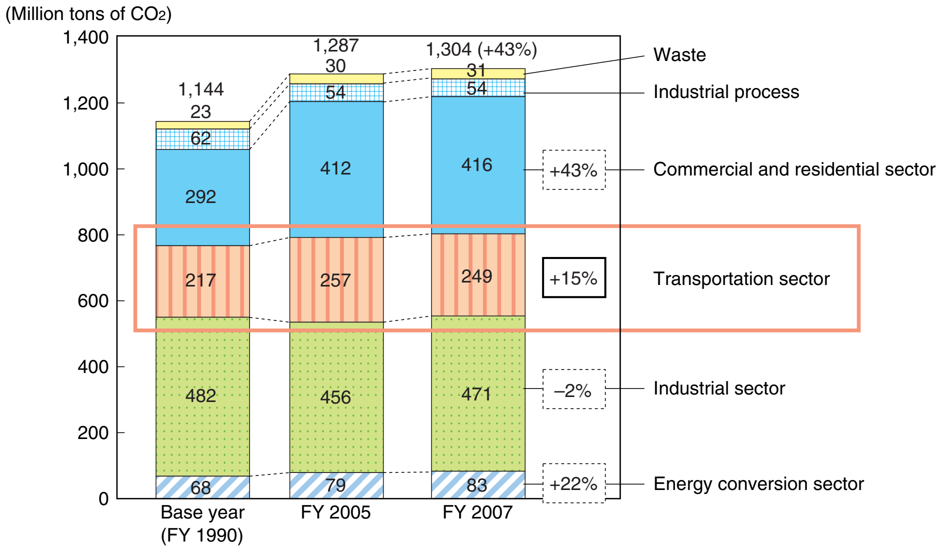
I Trends in CO_2 Emissions in the Transportation Sector

1 Urgent need to reduce CO_2 emissions in the transportation sector

Japan is the world's fifth-largest emitter of carbon dioxide (CO_2). According to the Kyoto Protocol adopted in 1997, Japan was obliged to reduce its greenhouse gas emissions to 6 percent below the level of fiscal 1990 by 2012. However, in fiscal 2007, emissions had actually increased by 160 million tons (14%) relative to the fiscal 1990 level (Figure 1). When we look at the sources of these emissions, we find that the transportation sector is the third-largest producer next to the industrial sector and the commercial and residential sector. The rate of increase in CO_2 emissions in this sector is also large, at 15 percent. Because vehicles are responsible for close to 90 percent of the CO_2 emissions within the transportation sector, controlling emissions from vehicles will make a huge contribution to reducing Japan's overall level of emissions.

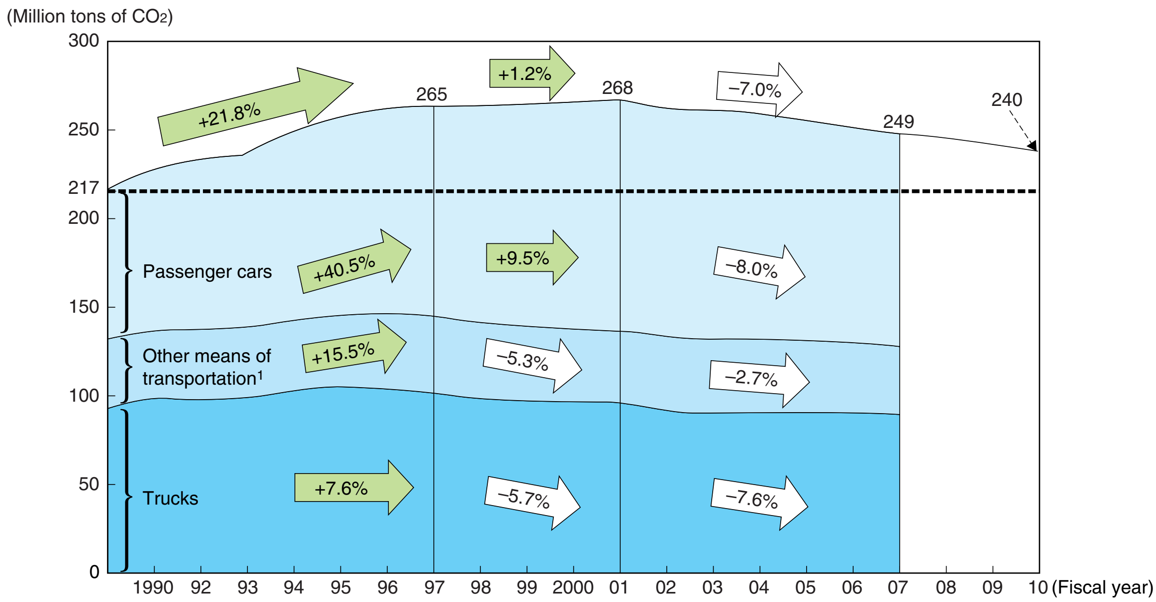
When we look at the CO_2 emissions from vehicles, we see that they peaked around fiscal 2001 and have been falling ever since (Figure 2). By type of vehicle,

Figure 1. Japan's carbon dioxide (CO_2) emissions



Note: The amounts indicated above are CO_2 emissions caused by power and heat generation that are distributed to each end-use sector.
Source: Compiled based on "The GHGs Emissions Data of Japan (1990 – 2008)," Greenhouse Gas Inventory Office of Japan.

Figure 2. Trends in CO_2 emissions from the transportation sector



Notes: 1) Other means of transportation include buses, taxis, trains, watercraft and aircraft. 2) The target value for fiscal 2010 is the value that was obtained by reviewing the 2005 assumptions in consideration of the effect of the reduction measures taken after 2005 and is indicated in the revised Kyoto Protocol Target Achievement Plan determined by the Cabinet Council on March 28, 2008.
Source: Compiled based on "Measures against Global Warming in the Transportation Sector," Ministry of Land, Infrastructure, Transport and Tourism of Japan;http://www.mlit.go.jp/sogoseisaku/environment/sosei_environment_tk_000006.html (in Japanese).

however, there is a huge difference between the levels of emissions from passenger cars and from trucks. Although emissions from passenger cars hit a peak in fiscal 2001 and subsequently exhibited a falling trend, emissions have actually increased sharply relative to fiscal 1990 levels, being approximately 45 percent higher in fiscal 2007. On the other hand, emissions from trucks have been falling since fiscal 1996, and stand at around 4 percent less than those in fiscal 1990. To reduce Japan's overall CO_2 emissions, therefore, it is vital that we address the reduction of CO_2 emissions from passenger cars.

2 Targeting the reduction of CO_2 emissions from passenger cars

The average on-road fuel efficiency of in-use passenger cars (obtained by dividing the distance traveled by the quantity of fuel consumed) has been steadily improving (Figure 3). Therefore, it is assumed that the main reason for the drop in CO_2 emissions from passenger cars since fiscal 2001 is the improvement in fuel efficiency.

Because car ownership is expected to be on the decline, the total mileage traveled by passenger cars is also expected to decline. Moreover, the average certified fuel efficiency of new passenger cars (this refers to the harmonic mean weighted by the number of cars sold for each type of vehicle with respect to the Japan's 10- and 15-mode fuel efficiency for each type of new vehicle sold each fiscal year (the 10-mode fuel efficiency assumes 10 running patterns in cities, while the 15-mode fuel efficiency assumes 15 running patterns in suburbs)) has been improving since fiscal 1997. Accordingly, as passenger cars are replaced with new ones, the average certified fuel efficiency of in-use passenger cars (this refers to the harmonic mean weighted by the number of cars in use for each age of car with respect to the average certified fuel efficiency for each age of passenger cars in use at the end of each fiscal year) is also expected to improve. This will eventually improve the average on-road fuel efficiency of in-use passenger cars. Accordingly, a natural attrition in CO_2 emissions can be expected to some extent in the future.

However, to achieve a 25-percent reduction in CO_2 emissions relative to 1990 levels by 2020, the reduction in the amount of CO_2 emissions from passenger cars will have to be accelerated.

II Technological Approaches and Policy Trends to Reduce CO_2 Emissions from Passenger Cars

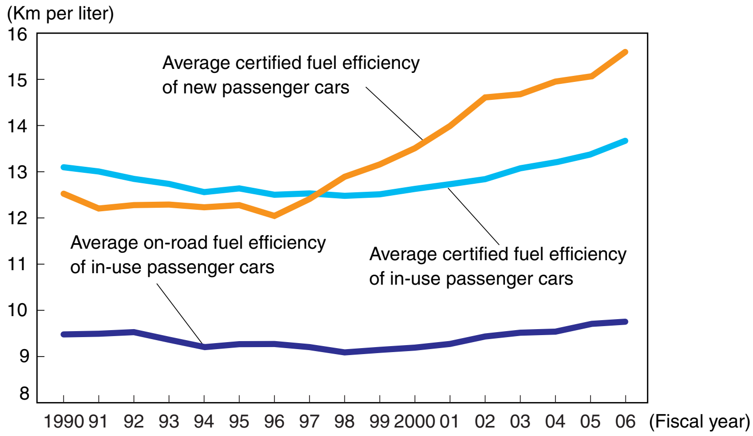
1 Ideas for reducing CO_2 emissions from passenger cars

There are four basic approaches to reduce CO_2 emissions from passenger cars (Table 1).

(1) Reducing the demand for travel itself
(2) Rather than using cars for making journeys, using means of transportation that produce less CO_2 emissions
(3) Reducing CO_2 emissions from cars that are already on the road
(4) Reducing CO_2 emissions from new cars

As a means of achieving Item (1) above, that is, reducing the demand for travel itself, various approaches are conceivable, which include reducing the need for travel by using alternative means such as telecommuting and

Figure 3. Trends in average fuel efficiency of gasoline-fueled passenger cars



Notes: 1) Average certified fuel efficiency of new passenger cars: This refers to the harmonic mean weighted by the number of cars sold for each type of vehicle with respect to Japan's 10- and 15-mode fuel efficiency for each type of new vehicle sold each fiscal year. Average certified fuel efficiency of in-use passenger cars: This refers to the harmonic mean weighted by the number of cars in use for each age of car with respect to the average certified fuel efficiency for each age of passenger car in use at the end of each fiscal year. Average on-road fuel efficiency of in-use passenger cars: This refers to the value obtained by dividing the distance traveled by the quantity of fuel consumed. 2) Figures for fiscal 2006 are preliminary data.
Source: Ministry of Land, Infrastructure, Transport and Tourism of Japan.

Table 1. Concept of reducing CO_2 emissions from passenger cars

Approaches	Examples
(1) Reducing the demand for travel	• Reducing the need for travel itself (e.g., videoconferencing) • Reducing the distance traveled (e.g., urban compaction)
(2) Using means of transportation that produce less CO_2 emissions	• Using bicycles • Using public transit such as buses and trains
(3) Reducing CO_2 emissions from cars that are already on the road	• Promoting eco-driving • Improving traffic flow (avoiding traffic jams) • Using low-carbon fuels (biofuels)
(4) Reducing CO_2 emissions from new cars (improving fuel efficiency)	• Using lightweight bodies, energy management • Using diesel fuels and high-concentration biofuels • Using electric drive vehicles

videoconferencing, and reducing the distance traveled such as reducing the distances between homes and workplaces and promoting the compact city concept. For Item (2), the most obvious alternative means of transportation that will reduce CO_2 emissions is, for short distances, the bicycle. While public transit such as buses and trains can be used for large numbers of people, high-speed trains (*shinkansen*) and aircraft could be considered for much greater distances.

The following sections discuss reducing CO_2 emissions from cars that are already on the road (Item (3) above) and those from new cars (Item (4) above), which constitute the main theme of this paper. Trends in government policy are also introduced. Before we go into detail, the policies adopted by the Japanese government that pertain to a vehicle's powertrain (engine and transmission) are outlined in Table 2. The major policies of the past few years have set the targets and have indicated specific approaches (methods and means) to achieve such goals with respect to (1) fuel economy standards, (2) market penetration of biofuels, (3) the spread of diesel vehicles and (4) the spread of electric drive vehicles.

2 Reducing CO_2 emissions from vehicles that are already on the road

Measures that have already been taken to reduce CO_2 emissions from passenger cars include the promotion of eco-driving, improvement of traffic flow and the use of low-carbon fuels.

Of these measures, the most cost-effective way of reducing CO_2 emissions appears to be the promotion of eco-driving. Eco-driving is one of the actions recommended in the Challenge 25 Campaign launched by the Japanese government. For eco-driving, ten items are recommended under "Eco-Drive 10[1]," which includes "gentle acceleration" and "no idling." By starting up more gently than usual (the aim is reaching 20 km/h in the first five seconds) and eliminating idling, fuel consumption can be reduced by about 10 percent.

When the average speed of a vehicle is low, as when in a traffic jam, its CO_2 emissions will increase. The available data indicate that when the average speed is 20 km/h, CO_2 emissions will be 40 percent higher than when the average speed is 40 km/h. Therefore, if we eliminate traffic congestion and improve traffic flow, we could greatly reduce CO_2 emissions. To this end, various approaches are being considered. These include conventional approaches such as providing right-turn lanes and overhead crossings at intersections, as well as advanced IT-based approaches such as traffic signal control and providing route guidance by predicting the occurrence of traffic jams.

Low-carbon fuels include biofuels. Such biofuels refer to gasoline that contains bioethanol, which is made from sugar cane and other plants. Because these plants absorb CO_2 while they grow, the amount of CO_2 emissions can be considered zero (it was decided to deem emissions zero under the Kyoto Protocol) when plant-derived bioethanol is burned. Therefore, when biofuel is used, CO_2 emissions can be reduced by an amount equal to the proportion of bioethanol in the gasoline.

In Brazil and the United States, where the production of biofuels is well advanced, E100 cars and E85 cars[2] are relatively commonplace. Meanwhile, the Japanese government has set a target in its New National Energy Strategy that aims at all new cars being capable of supporting E10 and two-thirds of all cars including those already on the road being capable of supporting E10 or ETBE7[3] by fiscal 2020.

The use of biofuels with relatively high concentrations of ethanol such as E10 requires the modification of engine systems to support the use of such fuels. Because such modifications are not required for low-concentration biofuels[4] such as E3 and ETBE8, it is likely that the Japanese market will first see the spread of relatively low-concentration biofuels.

In Japan, low-concentration biofuel is known as "bio-gasoline." All major oil companies are starting production of bio-gasoline in fiscal 2010. Nippon Oil Corporation, which is moving ahead of other companies, plans to start production at three refineries and to double the number of gas stations selling this fuel throughout the country to 2,000 outlets (slightly more than 20% of

Table 2. Trends in Japan's policies pertaining to automotive energy

	April 2005	March 2006	May 2006	May 2007	
Major policy	Kyoto Protocol Target Achievement Plan	Biomass Nippon Strategy	New National Energy Strategy	"Cool Earth 50" Initiative	Next-Generation Vehicle and Fuel Initiative
Outline	Formulation of a plan for the achievement of the targets set under the Kyoto Protocol that became effective in February 2005	Clarification of the problems and measures to facilitate the use of biomass fuels (the December 2002 version of the strategy was revised)	Setting medium- and long-term visions with specific numerical targets as a milestone; at least another 30% improvement in energy efficiency by 2030; reduction of oil dependence for transport energy by 20% by 2030	Setting a long-term strategy aimed at global reduction of greenhouse gas emissions	Clarification of measures to achieve the targets set under the New National Energy Strategy
CO_2 reduction target	• Reducing CO_2 emissions by 6% below 1990 levels during the period between 2008 and 2012 • Reducing 25.40 million tons of CO_2 emissions from automobiles alone (by 2010)			• Cutting global emissions in half from the current level by 2050	
Target for introducing next-generation vehicles					
Fuel economy standards			• Establishing new standards to promote greater fuel efficiency during fiscal 2006		• Improving fuel economy standards for passenger cars to 16.8 km/l in JC08 mode[6] by 2015 (Law Concerning the Rational Use of Energy, July 2007)
Spread of biofuels	• Replacing 500,000 kl (oil equivalent) of transportation fuels with biomass-derived fuels by fiscal 2010 • The oil industry aims to produce 210,000 kl (ETBE[3]) by fiscal 2010		• Developing biomass fuel supply infrastructure • Building a structure that enables the use of bioethanol blended gasoline consisting of 10% bioethanol and 90% gasoline		• Developing technology to produce cellulose-based ethanol • Introducing bioethanol in stages
Spread of diesel vehicles			• Studying measures to promote a shift to diesel fuels		• Studying incentive programs and other schemes for full-fledged spread of clean diesel vehicles after 2009
Spread of electric drive vehicles			• Studying measures to promote the development and spread of HEVs, EVs and FCVs • Developing technologies for automobile rechargeable batteries through collaboration among industry, government and academia		• Improving battery performance and reducing its cost aiming at full-fledged spread of compact EVs by 2010, PHEVs by 2015 and EVs by 2030

Note: CNG vehicle = compressed natural gas vehicle, EV = electric vehicle, FCV = fuel cell vehicle, HEV = hybrid electric vehicle, PHEV = plug-in HEV.
Source: Compiled based on various materials.

all affiliates). All other major oil companies have also committed to beginning the production of bio-gasoline. Accordingly, in the Kanto region where most refineries are concentrated, it is expected that the vast majority of gasoline sales will be of bio-gasoline.

Although the per-liter manufacturing cost of bio-gasoline is expected to be a few yen more than that of conventional gasoline, the major oil companies are not passing this cost on to the customer so that bio-gasoline will cost no more than conventional gasoline. However, most of the bioethanol used in bio-gasoline production is imported from countries such as Brazil, with only a limited amount being procured in Japan. Given that the transportation of this ethanol itself produces CO_2

Table 2. Trends in Japan's policies pertaining to automotive energy (Continued)

	March 2008	July 2008		June 2009	September 2009
Major policy	Cool Earth Energy Innovative Technology Plan	Clean Diesel Promotion Policy	Action Plan for Achieving a Low-Carbon Society	Mid-Term Target for Addressing Global Warming	Speech by Prime Minister Hatoyama at the UN Summit on Climate Change (New Mid-Term Target)
Outline	Identification of 21 priority innovative technologies toward substantially reducing CO_2 emissions by 2050; creation of roadmap	Formulation of basic policy for promoting the spread of clean diesel vehicles	Specific measures for substantially reducing CO_2 emissions by 2050	Target set by the Aso administration for reducing CO_2 emissions by 2020	Hatoyama administration revision of the target for reducing CO_2 emissions by 2020
CO_2 reduction target			• Reducing 60 to 80% of Japan's current level of greenhouse gas emissions by 2050	• By 2020, reducing Japan's greenhouse gas emissions by 15% from the 2005 level	• By 2020, reducing Japan's greenhouse gas (CO_2) emissions by 25% from the 1990 level
Target for introducing next-generation vehicles			• By 2020, increasing the number of next-generation vehicles (HEVs, PHEVs, EVs, clean diesel vehicles and CNG vehicles) to 50% of new cars and 20% of in-use cars ("Plan to be the First Nation that Popularizes Eco-Cars")		
Fuel economy standards					
Spread of biofuels	• Reducing production costs in processes using mass-produced non-food crops to 40 yen/l by 2015				
Spread of diesel vehicles		• Offering tax incentives; central and local governments to set a trend in using clean diesel vehicles			
Spread of electric drive vehicles	• Improving battery performance and reducing its cost aiming at 200,000 yen/kWh for 100 Wh/kg and 20,000 yen/kWh for 200 Wh/kg by 2020				

Note: CNG vehicle = compressed natural gas vehicle, EV = electric vehicle, FCV = fuel cell vehicle, HEV = hybrid electric vehicle, PHEV = plug-in HEV.
Source: Compiled based on various materials.

emissions, there is a clear need to increase domestic procurement[5].

If, by fiscal 2020, biofuels with an ethanol content equivalent to E10 are used in all vehicles including those already on the road, we can roughly say that CO_2 emissions will be reduced by 10 percent.

3 Reducing CO_2 emissions from new cars

In Japan, fuel economy standards have been established and imposed on new cars. While fuel economy standards were first set in fiscal 1999 for achievement in fiscal 2010, these targets were actually achieved by fiscal

2005. Accordingly, in fiscal 2007, new fuel economy standards (16.8 km/l in JC08 mode[6]) were set for achievement by fiscal 2015. If we look at these standards globally, we find that Japan's fuel efficiency standards are second only to Europe's toughest fuel efficiency requirements (Figure 4)[7].

To meet these new fuel economy standards, automobile manufacturers have developed various technologies. Typical fuel economy technologies include: (1) lightweight bodies, (2) improved energy efficiency (energy management), (3) improved engine technologies (in gasoline engines), (4) use of diesel (light oil) fuels and high-concentration biofuels and (5) electric drive vehicles.

Because it is clearly wasteful to use a vehicle weighing an average of 1.5 tons to move a person weighing approximately 50 to 70 kg, reducing the weight of a vehicle's body has long been a goal of automobile manufacturers. Reducing the weight of a passenger car's body by 100 kg can improve fuel economy by about 1 km/l. Currently, Japanese automobile manufacturers are striving to reduce the weight of automobile bodies, with an industry-wide average reduction of about 15 percent expected for almost all types of vehicles by 2020. To achieve this goal, in addition to reducing the number of components by integrating functions, manufacturers are using high tensile steel sheets and aluminum alloys, and are also using magnesium alloys, carbon fiber reinforced plastics and glass fiber reinforced plastics for higher grade cars.

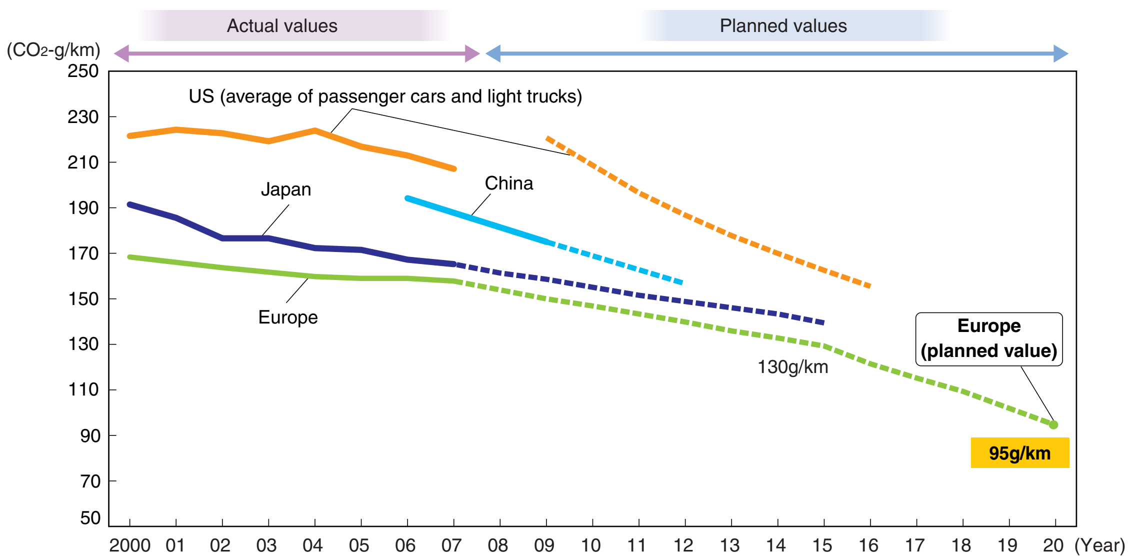
As described in Section 2 of this chapter, "Reducing CO_2 emissions from cars that are already on the road," currently, the use of low-concentration biofuels in the levels of E3 to E10 is being promoted in Japan. Unlike Brazil and the US, where raw materials can be procured domestically, the use of high-concentration biofuels such as E85 and E100 is not currently part of government policy. At the Conference on Eco-Fuel Utilization Promotion organized by the Ministry of the Environment, it was stated, "because of Japan's limited ethanol resources, we are currently not at the stage of discussing the promotion of high-concentration biofuels." Thus, high-concentration biofuels are not expected to become common in the Japanese market for some time.

The production of diesel engines results in less CO_2 emissions than those from gasoline engines. In addition, diesel engines themselves are more thermally efficient and offer 20 to 30 percent better fuel economy as compared to gasoline engines. Diesel vehicles are well accepted in Europe as environmentally friendly diesel vehicles (clean diesel vehicles). Such vehicles currently account for more than 50 percent of all new car sales.

In Japan, however, diesel-powered passenger cars are very poor sellers. Japanese consumers have a bad impression of diesel vehicles. Coupled with this bad impression, the higher price of such vehicles has led to the proportion of diesel vehicles among all new car sales as being close to zero. Although studies have been undertaken to politically promote the introduction of diesel vehicles, the measures considered lack feasibility and no target has been set. It seems highly unlikely, therefore, that diesel cars will become any more commonplace in Japan in the future.

While little progress can be expected for the use of high-concentration biofuels and diesel cars, one area that has recently seen considerable progress is that of electric cars (vehicles with electric power trains). Recently, considerable activities have been under way in this field and we can say that hardly a day goes by when we do not see mention of either HEVs or EVs in the news.

Figure 4. Fuel economy standards in Japan, the US, Europe and China



Source: Actual values are based on materials published by the Ministry of Land, Infrastructure, Transport and Tourism of Japan; the National Highway Traffic Safety Administration (NHTSA) of the US; the European Automobile Manufacturers' Association (ACEA) and interviews.

III Prospects and Challenges Facing the Use of Electric Drive Vehicles

Among the various measures that have been discussed so far as a means of reducing CO_2 emissions, increased attention is being paid to electric drive vehicles as the key to reducing CO_2 emissions from passenger cars.

1 Definition of electric drive vehicles

The umbrella term "electric drive vehicles" includes "hybrid electric vehicles (HEVs)," "plug-in HEVs (PHEVs)" and "electric vehicles (EVs)."

An HEV is a car that uses both an electric motor and a conventional engine. Prime examples include the Toyota "Prius" and the Honda "Insight."

A PHEV has a larger secondary battery (a rechargeable battery, hereafter referred to as the "battery") than that of an HEV, which can be charged by plugging the car into an external power source. In one type, called the "series (or range extender)" type, a relatively large 15-kWh battery is installed and the engine is used only to charge the battery. In another type, called the "series-parallel" type, a relatively small 5-kWh battery is used intermittently together with the engine. An example of the former type is the "Chevrolet Volt," which is being developed by General Motors, while the already released Toyota "Prius Plug-in Hybrid" is an example of the latter.

An EV is driven purely by an electric motor. Because it has no engine, it produces zero CO_2 emissions. In 2009, Mitsubishi Motors Corporation offered its "i-MiEV" and Fuji Heavy Industries, Ltd. offered the "Subaru Plug-in Stella" to fleet operators. In December 2010, Nissan Motor Co., Ltd. will launch its "Leaf" EV.

The main reasons for this flurry of EVs include the recent progress in battery technology. Although there have been two EV booms in the past, in neither case did the technology take off due to poor battery performance (large and heavy). However, the current crop of EVs uses lithium ion batteries (LIB). Compared to the lead-acid and nickel-metal hydride batteries of the past, the LIB types offer greatly improved performance such as in terms of capacity density and weight density, thus making the realization of EVs much more feasible.

2 Advantages and disadvantages of each type of electric drive vehicle

Each type of electric drive vehicle has its own advantages and disadvantages in terms of CO_2 emissions, cost and charging infrastructure (Table 3).

An HEV can be handled in the same way as a conventional engine-powered car and people can easily become familiar with it. However, it produces higher CO_2 emissions than either the PHEV or EV type because most of its power is from an engine. While an EV, on the other hand, produces zero CO_2 emissions and is environmentally friendly, it has several disadvantages including (1) the price of the vehicle is relatively high, reflecting the cost of the large number of costly batteries, (2) even with a large battery capacity, the range of the vehicle is limited to 100 – 200 km per charge and (3) the batteries require frequent recharging (often daily). Furthermore, to allow users to travel greater distances with relative ease, a public fast-charging infrastructure must be developed. The PHEV is positioned midway between the HEV and the EV types, tending towards either type according to the capacity of the installed batteries.

A "well-to-wheel" analysis of fuel efficiency (from crude extraction to burning in a vehicle's engine) shows that CO_2 emissions of an HEV are reduced to around 40 to 50 percent of those of conventional internal combustion engine vehicles (Table 3). In addition, because a PHEV can travel relatively far in EV mode, the value for these vehicles can be reduced to around 30 percent. When we look at an EV, the value is between 0 and 20 percent. In the case of an EV, even though the vehicle itself produces zero emissions, the well-to-wheel value varies depending on how the power used to charge the car is generated. The CO_2 emissions produced when electricity is generated by a nuclear, wind or solar facility are close to zero. Therefore, an EV that is charged

Table 3. Advantages and disadvantages of vehicles by powertrain (engine and transmission)

Powertrain	Well-to-wheel CO_2 emissions (gasoline vehicle = 100)		Vehicle cost (simplicity of vehicle system)		Cost of infrastructure development (necessity of charging infrastructure)	
Gasoline	NA	100	Good	Simple (engine only)	Good	No new infrastructure is required
Hybrid (HEV)	Fair	40 – 50	Fair	Engine + electric power	Good	No new infrastructure is required
Plug-in HEV (PHEV)	Fair	30	Poor	Engine + electric power + charging function	Fair	Better if charging infrastructure is available (distance where electric power is used can be extended)
Electricity (EV)	Good	0 – 20	Poor	Electric power + charging function However, secondary batteries are heavy and expensive	Poor	Requires charging infrastructure

using power generated by any of these means will have negligible well-to-wheel emissions[8]. To achieve the mid-term CO_2 reduction targets, the Japanese government is aiming to increase the ratio of "zero-emission power sources" such as nuclear power and new energy sources such as those mentioned above to more than 50 percent of all power generated, which is likely to lead to a future increase in the number of EV cars that can operate on cleaner power.

The introduction of electric drive vehicles is also effective in terms of energy security. Internal combustion engine vehicles can operate only on gasoline that is derived from petroleum. However, PHEV and EV cars can derive their power from a variety of electricity generation fuels and methods.

3 Moves of venture companies in the EV market

An EV is relatively simple and has fewer components and parts than a gasoline-powered vehicle. It does not involve the considerable work needed to ensure compliance with automobile exhaust gas regulations. Therefore, primarily in other countries, many venture companies have entered the EV market.

In the US, for example, Tesla Motors put its electric sports cars on the market in 2008, and has already sold more than 1,000 cars. Coda Automotive, also of the US, plans to sell electric sedans (the sedan type is the best-selling type). Tesla Motors obtained its electric drive system technology from ACP of the US, while the actual drive unit is procured from a Taiwanese company. Coda Automotive has its vehicles produced in China by a medium-scale manufacturer, Hafei Automobile Industry Group Co. Ltd., on an OEM basis. In both cases, the business model relies on a division of labor.

Meanwhile, in some areas of China, very cheap, low-speed electric drive vehicles, which are referred to by NRI as light EVs (LEVs) to distinguish them from normal EVs, are sold (Figure 5). These cars are of poor quality and do not meet crashworthiness standards. While the central government does not allow these cars on public roads, some local governments such as Shandong Province where LEV manufacturers are clustered permit their running on public roads as a means of stimulating local industry. Whether the central government will allow such vehicles to be used on all public roads is still unclear. Nevertheless, there could be a market for LEV cars in rural China.

Apart from this, there is a very good chance that the Chinese government will promote the development and spread of normal EV cars from the mid-term perspective as a means of catching up with and surpassing the automobile manufacturers of advanced countries. Because this kind of policy would be a major threat to Japanese automobile manufacturers, it is necessary to pay very careful attention to any such move.

Figure 5. China's low-speed electric drive vehicle

Manufacturer: Shifeng
Price: About 30,000 yuan
Seating capacity: 4 persons
Maximum speed: 50 km/h
Driving range: 150 km (decreases to 50 km after 3 years; battery replacement costs 400 yuan.)
Battery type: Lead-acid

4 Future electric drive vehicle market trends

As we have discussed so far, there are actually many different aspects to the development of electric drive vehicles. However, the author believes that up until 2020, the greatest market penetration among electric cars will be achieved by HEVs. As mentioned previously, an HEV can be treated in the same way as a conventional gasoline-powered vehicle, and does not need any special charging infrastructure. Additionally, because the capacity of its expensive battery is relatively small (about 1 kWh), the price of the vehicle can be kept low. The cheapest-ever Prius and Insight models that were put on the market in 2009 sold at around 2 million yen, making them competitive with gasoline-powered cars.

Following HEVs, it is likely that PHEVs will be the next segment to take off. Series-parallel PHEVs needing relatively small battery capacity will be most competitive in terms of price. Because a 5-kWh battery can power a vehicle for around 20 km, the vast majority of daily journeys would be covered. When an unusually long-distance journey is to be undertaken, the car can be used as a regular HEV. Therefore, it is very likely that a PHEV would be purchased as a first vehicle (the first passenger car purchased).

However, with conventional selling methods, the sales of EVs are not expected to grow. At current levels, batteries are very expensive, standing at around 150,000 yen/kWh. An EV requires more than 15 to 20 kWh of large battery capacity. Even if battery cost could be reduced to 50,000 yen/kWh, a 20-kWh battery would still cost 1 million yen, greatly increasing the cost of the vehicle. Even though power is consumed at the rate of 10 km/kWh, a vehicle could travel only 200 km per charge. This would make travel over any greater distance difficult and far from worry-free, especially if there is not a well-established network of fast chargers.

In addition, because merely selling electricity provides little opportunity for profit, there is little chance of fast chargers becoming commonplace. If the current cost (around 20 yen/kWh) of electricity for household use is applied, only about 400 yen could be billed for a full charge of 20 kWh. This means that it would be very difficult to recover the cost of a fast charger, which costs 3 to 4 million yen (excluding installation fees). Therefore, when thinking about reducing CO_2 emissions, it might be too much and too soon to think about using EVs.

IV Outlook and Challenges Related to the Spread of EVs

If EVs are to become more popular, a variety of innovations will be necessary. In terms of technologies, not to mention those that reduce battery costs, there is a need for the development of technologies to improve power efficiency (energy-efficient drive technology) and to effectively use battery capacity. Even though a large-capacity battery is installed in an EV, usually only about 50 percent of the available capacity is used. If it becomes possible to draw on 100 percent of its capacity, battery capacity could be halved, achieving major cost reductions.

There is also considerable room for business model innovation. For example, the concept of "battery sharing" has been proposed to lower battery costs (Table 4). In the US, venture company Better Place is attempting to rapidly popularize EVs by providing them with replaceable batteries. An EV's batteries are automatically replaced with a fully recharged set at a battery exchange station, enabling rapid recharge of the car. In this way, the cost of these expensive batteries is shared with others, and the rate of utilization is improved. This business model enables quick recovery of costs.

The rate of utilization can also be improved by applying EVs to car-sharing schemes. This concept would also allow the cost of EVs to be recovered as soon as possible. Kanagawa Prefecture has a scheme in which electric cars purchased by the prefecture are rented to its citizens on weekends and holidays[9]. These vehicles are used for official work by the prefecture during the week and rented to citizens on holidays and weekends. This scheme increases the rate of utilization and improves affordability. It is also seen as a means of making citizens more aware of EVs. EV car sharing is also being attempted as a new business line among gas stations and convenience stores.

Another new business model known as "vehicle to grid" (V2G) is one of the items being discussed as part of the Smart Grid concept. Basically, excess electrical power that is stored in the batteries of EVs is fed back to the grid. In the US, in particular, where power outages occur frequently, drawing on this stored power through the V2G system could be one means of stabilizing the power supply. Furthermore, because this could earn cash for the owner of the vehicle in the form of payments from the power company, it could serve as an incentive to purchase an EV.

Nissan Motor Co., Ltd., which is very positive about the spread of EVs, is working together with Sumitomo Corporation in looking into possible reuse applications for used EV batteries. For example, used EV batteries could be used as devices for storing energy in homes and offices. Suppose an EV battery originally costs 1 million yen. If this battery could be sold for 300,000 yen as a used battery, the price of the EV could be reduced by the same amount.

To validate these business models, many issues remain to be resolved such as ensuring long battery life and establishing a method for determining the price of a used battery.

Innovation in terms of consumer lifestyles might also be needed. For example, one's own compact EV could be used for making the short journeys that are typical of weekdays, while a rented gasoline-powered vehicle could be used for making long journeys on holidays and weekends. If the battery capacity of the EV could

Table 4. Reducing battery costs through "sharing"

		Industrial moves		
		Automobiles		Other industries
Target	Battery alone	Better Place's business model (EV with a replaceable battery)	V2G (Smart Grid)	Reuse of used batteries (for stationary use)
	Electric vehicle	EV car sharing		

Note: V2G = Vehicle to Grid (supplying electric power stored in electric vehicles to power grids).

be made as small as possible, the price of the EV could be reduced. Furthermore, if the battery is charged at home, the required scale of a public charging infrastructure could be minimized. To this end, there is also a need for developing EVs offering new appealing features.

In the future, we will see intensified competition in developing new business models for the EV and charging infrastructure markets.

Notes

1 "Eco-Drive 10" (http://www.team-6.jp/ecodrive/10recommendation/index.html) (in Japanese).

2 Biofuel classifications are based on ethanol concentrations. The numbers refer to the proportion of ethanol in the fuel: "E100" refers to fuel containing 100 percent ethanol and "E85" means fuel directly combining 85 percent ethanol and 15 percent gasoline in terms of volume.

3 In addition to the above-mentioned types of biofuels in which ethanol is mixed directly with gasoline, there is also "ETBE" in which processed ethanol is mixed with the gasoline. Because ETBE is made from a synthetic compound of bioethanol and petroleum gas, the bioethanol content is reduced to about 40 percent. In terms of bioethanol content, "E3" and "ETBE7" each contain similar amounts of bioethanol.

4 Conference on Eco-Fuel Utilization Promotion.

5 *Nihon Keizai Shimbun*, January 10, 2010, and February 18, 2010.

6 The JC08 mode is a driving mode used to measure fuel efficiency in Japan. This new mode replaces the former "10/15" mode, which is closer to actual driving conditions than is the 10/15 mode, which had been used in the past, but had a large difference from actual on-road fuel efficiency.

7 In Japan, fuel efficiency standards use the unit of "km/l." To enable comparison with European CO_2 emission regulations, Japan's fuel efficiency targets are converted by multiplying the reciprocal of these targets by CO_2 content in gasoline (2,322g-CO_2/l).

8 Conversely, if an electricity generation method that emits large amounts of CO_2 is used, as in the case of thermal power generation, the well-to-wheel emissions of an EV could actually be greater than would those of a conventional gasoline vehicle.

9 http://www.pref.kanagawa.jp/osirase/taikisuisitu/car/04ev/0436/0436sharing.html (in Japanese).

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