DEVELOPMENT OF FUEL ECONOMY REGULATIONS AND IMPACT ON AUTOMAKERS

Kosuke Nishino
Industrial Studies Department I, Mitsui Global Strategic Studies Institute

EXECUTIVE SUMMARY

I. CHANGING CIRCUMSTANCES OF AUTOMOBILES

- As a result of the shale revolution in the U.S. and the slowdown of the Chinese economy, the supply and demand of oil has relaxed and the price of gasoline has stabilized at a low level, thus boosting the trend toward bigger and heavier vehicles, such as SUVs, in the U.S. and other parts of the world.
- The COP 21 discussions and agreement have shown significant progress toward the suppression of global warming by the cooperation of most countries in the world.

II. FUEL ECONOMY REGULATIONS BY COUNTRY AND REGION

- The introduction of fuel economy regulations has accelerated since 2010, and over 90% of the global automobile market is subject to regulations. A majority of the regulations in place are in accordance with the Corporate Average Fuel Economy (CAFE) standards.
- The European Union's 2021 target is the strictest in the world. It is nearly 30% more severe than the 2015 target. The distance to the targets varies by company, and U.S. and Korean companies are lagging.
- A distinctive feature of U.S. federal regulations is that the targets for passenger cars and light trucks are set separately, and the target for light trucks is laxer. Progress on fuel economy improvement differs significantly by country, and European companies are having a hard time meeting the targets.
- The targets after 2022 under current legislation are provisional and under review, and they could be revised by the Trump administration.
- Zero-emissions vehicle (ZEV) regulations enacted in ten states, including California, will be tightened from the latter half of 2017, and manufacturers are required to sell a designated share of ZEV like battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEV). Car manufacturers are required to respond.
- China's fuel economy regulations have been tightened a great deal toward 2020, to the similar level of those of Japan. In particular, Chinese brands are required to reduce fuel consumption significantly.
- In line with governmental policy of promoting new energy vehicles (NEV) such as BEV and PHEV, companies that make and sell these vehicles are given special preference in calculations of corporate average fuel consumption.

III. PROGRESS AND DIRECTION OF MEETING TIGHTENING FUEL REGULATIONS

- Improvement of fuel economy in the U. S. mainly relies on the improvement of internal combustion engine technology in combination with modest introduction of electrification. BEV, PHEV, and HEV (hybrid electric vehicle) will not be the mainstream technology, although BEV and PHEV will account for a certain share of sales among European manufacturers and HEV for some among Japanese manufacturers.
- In China, it is hard for most of companies to meet the 2020 regulations with only internal combustion engine technology. A cumulative 4 million NEVs need to be introduced by 2020 to reach the goal. The Chinese version of ZEV regulations is to be introduced in 2019 to promote improvement.

- In Europe, car manufacturers are forced to reduce dependence on diesel technology as a result of Volkswagen's diesel-gate scandal, and they are focusing more on electric drive.
- The diffusion of electrified vehicles varies by country in Europe. Countries with a high density of electrified vehicles, such as Norway and the Netherlands, are implementing powerful policy measures. For the mass diffusion of BEVs, generous policy support will be needed across European countries.

IV. CONCLUSION

- Fuel economy regulations, now widespread, will be strengthened in the long term, but the direction and progress differs by country, which reflects the differences in the situation of each country and region, such as the existence of consensus for better fuel economy and lower CO2 emissions and automotive industry policy.
- There are two groups of carmakers in terms of the technology of improving fuel economy. One group, which includes Toyota, is focusing on hybrid technology, and the other, made up of European companies, is now heading toward the introduction of battery electric vehicles and plug-in hybrid vehicles. Neither of group has found a clear scenario to meet fuel economy regulations after 2025.
- Fuel economy regulations could open up opportunities to re-examine the future form and function of the automobile, whose basic form has not changed since the last century. only 22.5 million in 2000. Also, the government censorship on Google or Facebook turned out to provide a boost to search engine Baidu or SNS operator Tencent.

PREFACE

With increasing concern about global warming, more and more countries and regions are introducing and tightening fuel economy regulations for automobiles. Carmakers are taking various measures to cope with this trend, including the electrification of powertrains in addition to the improvement of the efficiency of internal combustion engines, weight saving, reduction of running resistance, and so on. This movement could ultimately impact the form and the usage of the automobile, which basically has not changed since its inception.

The increasing availability of oil as a result of the shale revolution, on the other, has changed the supply and demand of oil, thus stabilizing gasoline prices in the U.S., and sales of larger cars, such as SUVs, and pickup trucks are growing. This is regressive for the saving of fuel. In China, the government leads the fostering of an automotive industry that leverages the mass introduction of electrified vehicles, and the fuel regulations play a part. As seen in these examples, the purpose and progress of and reactions to fuel economy regulations vary largely by country and region.

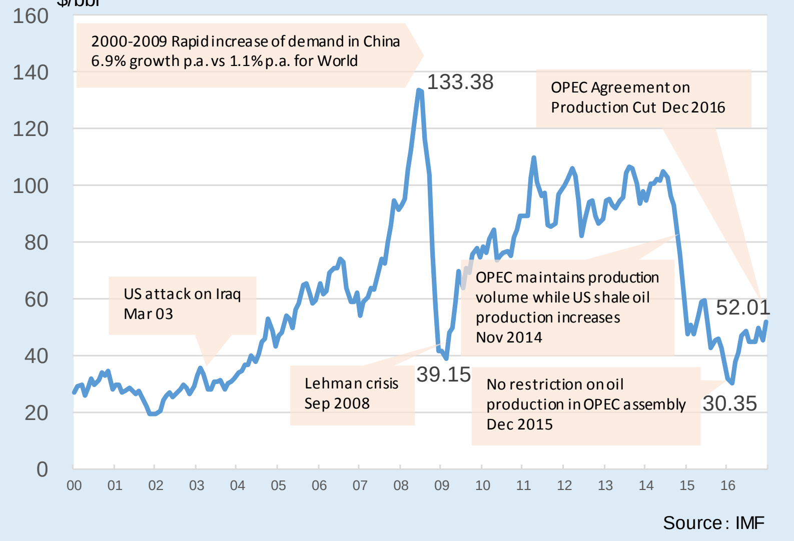
In this article, I overview fuel economy regulations of major regions and countries and carmakers' reactions to meet the regulations, examine the impact of regulations on the form, market, and the industry, and try to picture scenarios of future developments. In Chapter I, I overview the background of tightening fuel economy regulations, such as the supply and demand of fossil fuel and the move toward the reduction of global warming. Chapter II details the history and current status of regulations in Europe, the U.S., and China and spells out the characteristics of these markets. In Chapter III, based on an understanding of the current situation, I will try to formulate a view of the future direction of technologies and carmakers' strategic actions. Chapter IV summarizes the impact of fuel economy regulations on the market and industry as well as the state of regulations.

I.CHANGING CIRCUMSTANCES OF AUTOMOBILES

1. DEVELOPMENT OF FUEL PRICES

The global oil supply has significantly increased due to the activization of shale oil production in the U.S., and it has pushed oil prices down (Figure 1). As a result of agreement on the reduction of oil production among OPEC countries in November 2016, oil prices have inverted with the expectation that the surplus of oil will be mitigated. With the oil price hike, however, more and more shale oil production has become profitable, leading to increased production, thus creating a ceiling for the price hike. Technological innovation in shale oil production, further lowering the profitable line of business, is likely to push down the equilibrium.

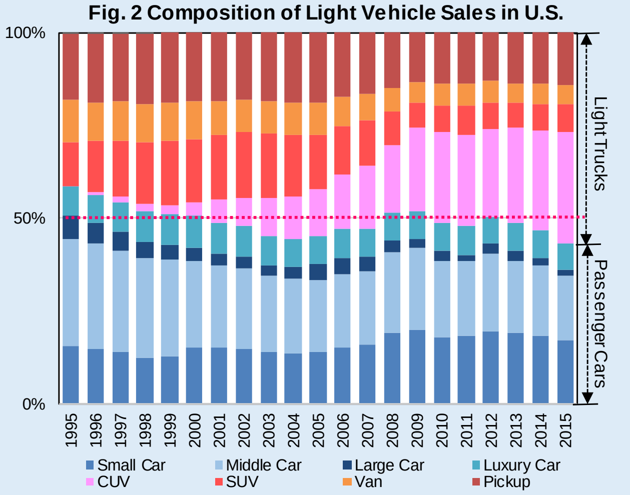
Fig. 1 Trend of Oil Price(WTI)



Although the price of gasoline in the U.S. rose above $3.50 per gallon for a period of time in 2012, it nosedived to the $1 range at the beginning of 2016 and has been hovering at the former $2 range lately.

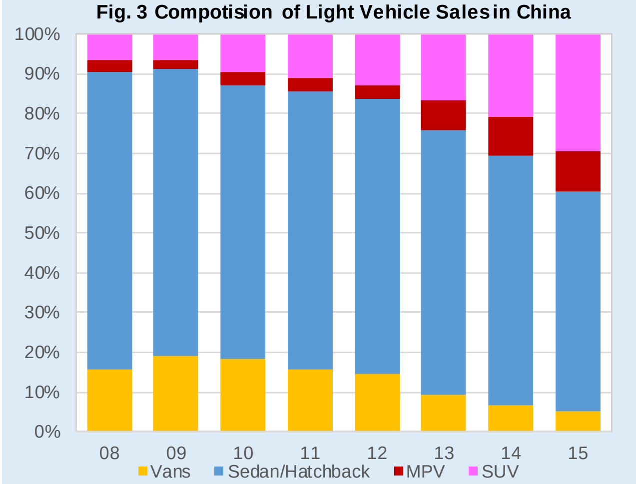
Sales of cars in the U.S. are greatly influenced by the interest rate for auto loans and the price of gasoline as car lease payments and the cost of gasoline account for a sizable part of a family's expenses. Interest rates in the U.S. still remain at a low level even after the rate hike at the end of 2015, the first time after in seven years, and the one that followed in 2016. These conditions have given rise to a rapid increase in long-term auto loans over the past seven years at extremely low rates. In combination with low gasoline prices, U.S. consumers are more and more inclined to larger vehicles such as SUVs and pickup trucks with low fuel economy. Historically, the U.S. light-duty vehicle market has been evenly divided between passenger cars (saloons and hatchbacks) and light trucks (SUVs, pickups, and vans), but the share of light trucks increased to 57% in 2015 (see Figure 2), which is a record high. On the contrary, sales of small cars and hybrids are decreasing year on year.

Fig. 2 Composition of Light Vehicle Sales in U.S.



Source : Ward's Auto

Fig. 3 Compotision of Light Vehicle Sales in China



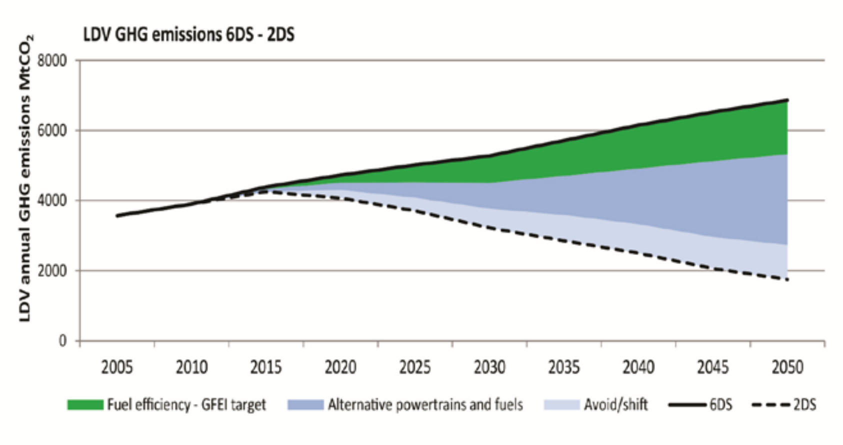
Source: Marklines

It is not only in the U.S. that SUV sales are increasing. In China as well, with economic development and the increase in personal income, people are going for more expensive and novel things, and more and more SUVs are selling. This trend was bolstered by local manufacturers' introduction of reasonably-priced SUVs to the market (see Figure 3). The trend of having more SUVs is universal and not specific to advanced or developing countries. The increase in SUVs, in a general sense, pushes weight and aerodynamic resistance up, thus deteriorating the average fuel economy of the fleet.

2. MOVES AROUND THE UNITED NATIONS FRAMEWORK CONFERENCE ON CLIMATE CHANGE

It was agreed by the 188 participating countries during COP 21 that they would try to suppress the increase in global average ambient temperate by the end of this century within at least 2 degrees Celsius, hopefully 1.5 degrees, of that before the industrial revolution. Participating countries are to set a target for greenhouse gas (GHG) emissions and report the progress every five years.

Fig. 4 Reduction Scenario of GHG from Light Duty Vehicles



Source: GFEI Fuel Economy State of the World 2016

The transportation sector is supposed to comprise about 20% of global GHG emissions. Reduction of emissions from motor vehicles, which comprise about 90% of the sector, is thus indispensable for the attainment of the target. The International Energy Agency (IEA) has made a calculation of the required reduction of emissions from light-duty vehicles to realize "the 2 degrees Celsius Scenario". According to the calculation, GHG emissions from light-duty vehicles (LDVs), including passenger cars and light-duty trucks) as of 2005 was 3.5 gigatons. If no measures are taken to reduce GHG emissions from LDVs, it is supposed that it would increase to 7 gigatons by 2050. In order to suppress warming by 2 degrees, the emissions amount must be reduced to about 2 gigatons in the same year (see Figure 4).

Global Fuel Economy Initiative (GFEI), a joint organization led by IEA, the United Nations Environment Programme (UNEP), and others, has set a target for global average fuel economy to attain the proposed reduction of GHG emissions from LDVs. According to the target, the average fuel economy of all vehicles on the globe has to be halved by 2050 compared with that of 2005, and that means that the average fuel economy of all LDVs sold around the world must be reduced to 4.2 L/100 km by 2030 from 8.3 L/100 km in 2005. This converts to a compounded annual reduction of 2.7% over 25 years (See Figure 5). In the GFEI report, the average LDV fuel economy of 20 countries (note) has decreased to 7.1 L/100 km in 2013 from 8.3 L/100 km in 2005 (which is 2.0% p.a.) but below the target. In order to achieve the target from 2014, improvements have to take place at the pace of 2.7% per year. Among those 20 countries, the average of OECD member countries (11) was reduced to 6.9 L/100 km from 7.1 L/ km during the same period (2.6% p.a.), the average of Non-OECD countries, on the other hand, barely reduced to 7.2 L/100 km from 7.3 L/100 km (0.2% p.a.).

Fig. 5 Fuel Economy Evolution Compared with GFEI Target

	Units	2005	2013	Improvement	2030
OECD Average	L/100km	8.6	6.9	-19.8% (-2.6% p.a.)	
	km/L	11.6	14.5		
	g/km	200	160		
Non-OECD Average	L/100km	7.3	7.2	-1.4% (-0.2% p.a.)	
	km/L	13.7	13.9		
	g/km	169	167		
G20 Average	L/100km	8.3	7.1	-14.5% (-2.0% p.a.)	
	km/L	12.0	14.1		
	g/km	193	165		
GEFI Target	L/100km	8.3		-49.4% (-2.7% p.a.)	4.2
	km/L	12.0			23.8
	g/km	193			97

Source : Fuel Economy State of the World 2016

As of today, there are about 1 billion LDVs in operation around the world, and this is supposed to increase to 2.2 to 3 billion by 2050. Of those, the majority of the increase comes from non-OECD (developing) countries. Therefore, achievement of the fuel economy improvement target hinges upon how it progresses in the developing countries.

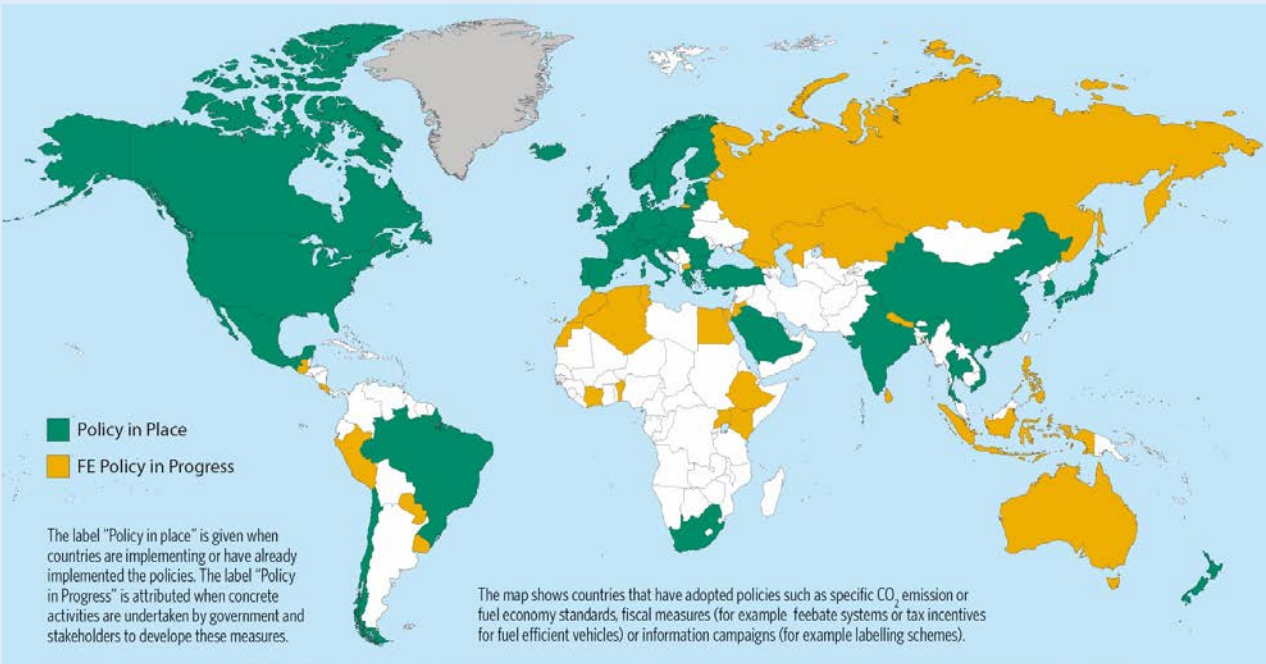
II. DEVELOPMENT OF FUEL ECONOMY REGULATIONS BY COUNTRIES AND REGIONS

1. OVERALL TREND OF FUEL ECONOMY REGULATIONS

Fuel economy regulations have a long history. They were first introduced in the United States, driven by the oil crisis in the 1970s, followed by Japan in the 1980s. With the adoption of the Kyoto Protocol at COP3 (3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change), the European Union and ACEA (European Automobile Manufacturers Association) agreed to set a voluntary goal for the fuel economy of vehicles, which was followed by EU regulations and goals for 2015 and 2021.

Among the developing countries, China adopted regulations relatively early, and the country is currently in the 4th stage of regulations for the 2020 target. After 2010, following the unprecedented hike in the price of oil before and after the financial crisis period, many developing countries, such as Brazil (2012), Mexico (2013), Saudi Arabia, India (2014), and Thailand (2015), have introduced fuel economy regulations, although the contents and strictness vary by country. It is estimated that over 90% of the global car market is subject to fuel economy regulations as of 2016, and the trend is supposed to continue (See Figure 6).

Fig. 6 Countries Fuel Economy Policy in Place

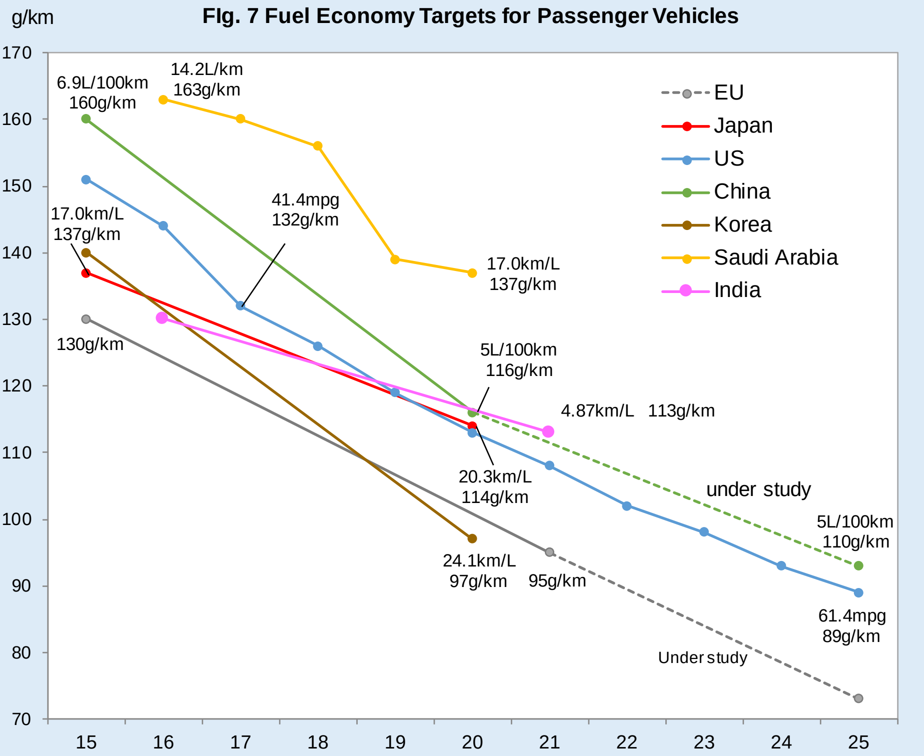


Source: GFEI Fuel Economy State of the World 2016

A majority of countries and regions have adopted the Corporate Average Fuel Economy (CAFE) method for regulations. In this method, the standard fuel economy target is set by vehicle weight or size. It is not required that each type of vehicle complies with the set target, but it is required that the weighted average of the fuel economy of the cars sold in the market by each vehicle manufacturer in a year meet the company's goal set by the average weight of the fleet. It is not easy to compare the level of various countries' regulations side-by-side, as the labeling method, division by weight or size, test driving cycle, and average weight and size of vehicles varies by country and region. For Europe, Japan and China, it is still easier to compare because the average weight of all vehicles sold is similar, but not in the case of the U.S., as target numbers are set by vehicle footprint (a multiple of vehicle tread and wheelbase) instead of weight, and the fleet average weight is significantly bigger there.

Figure 7 shows the average fuel economy target of each country under the EU method (CO2 emissions for a 1 km drive). Most of the countries set the immediate milestone year as 2020-2021, and the targets beyond that are under discussion.

Fig. 7 Fuel Economy Targets for Passenger Vehicles



Notes
1) All numbers are of passenger vehicles
2) Numbers are average of country's fleet. Converted into CO2 emissions per kilometer without taking the difference of test patterns.
3) 2025 numbers of Europe and China are under discussions.
Source: Regulation authorities, ICCT and Marklines

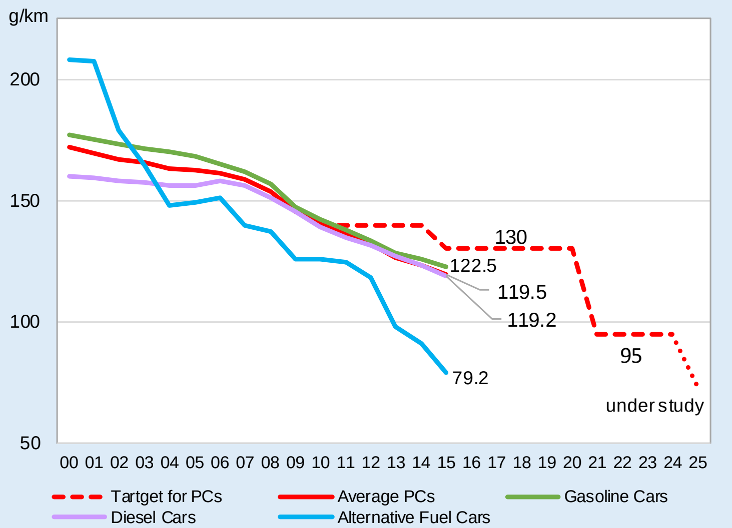
2. REGULATIONS BY REGION AND COUNTRY AND THEIR CHARACTERISTICS

(1) Europe

i) Outline of Regulations

In the EU, the 2015 target of average CO2 emissions from all passenger cars, which is 130 g/km, was introduced in 2008. As the amount of CO2 emissions is proportionate to the consumption of fuel, restrictions on CO2 emissions have virtually the same impact as fuel economy regulations. The reason the EU denominates by CO2 emissions amount is supposedly because the regulations started as a policy to counter climate change. The average CO2 emissions of the entire fleet in the EU in 2015 was 119.5 g/km, which exceeded the target for the year (see Figure 8).

Fig. 8 Target and Actual of Average Fuel Economy for EU PV Fleet



Source : European Environment Agency

Company groups that have sold a certain number of cars in a year in the EU region are assigned an average CO2 emissions target. The target number varies by the average weight of cars sold by the company. There were 13 groups (pools) of companies who were subject to regulations, whose annual sales in the EU exceed 300,000 units. Companies whose sales are less than 300,000 are exempted from full compliance and given a reduced target. There are four companies included in this category, of which three are Japanese (namely Subaru, Mazda, and Suzuki). Those whose sales are less than 10,000 units are exempted from the regulation.

As the period between 2015 and 2019 is subject to the 2015 regulations, those who have already met the target as of 2015 are unlikely to violate the target. It is necessary for them, however, to improve fuel economy every year, as they are not able to jump up in a year when the 2021 target of 95g/km is due.

The 2021 regulation number is 27% severer compared with 2015 one, and is converted to 24.4km/L (in case of gasoline car and 27.9km/L for diesel car) in the Japanese term, which is impressively high. As already mentioned, it is not easy to compare the regulations over countries, but there does not seem to be a controversy over the fact that EU standards are the severest in the world at this moment. Companies are required to pay 95 euro fine per unit for exceeding 1 g/km overage times the number of cars sold in a year.

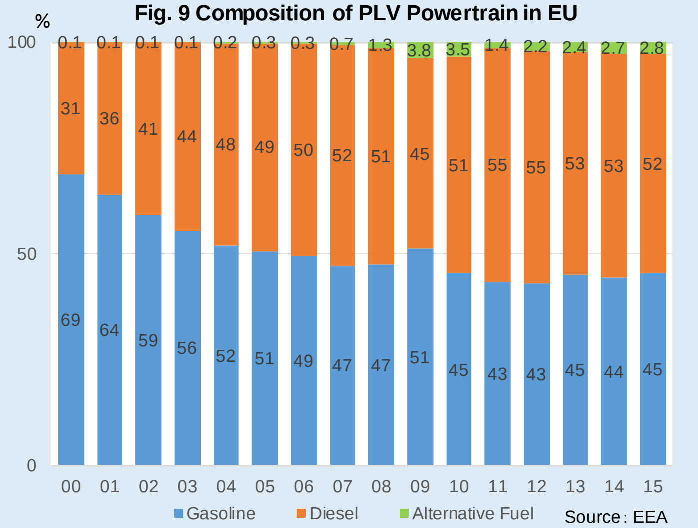
ii) Characteristics of EU Car Market

The outstanding characteristic of the EU is that gasoline and diesel cars each account for half of its car market (see Figure 9). The diesel engine is by nature higher in heat efficiency compared with the gasoline engine (see Figure 10, which indicates that the fuel economy of diesel cars, whose average weight is 20% heavier, is about the same as that of gasoline cars). In combination with less expensive diesel fuel, the fuel expense of diesel cars tends to be about 2/3 to 1/2 that of gasoline cars. As a result, the share of diesel cars is particularly high among company-owned cars, where the priority is on the economy of owning and operating. Diesel cars, also, are suitable and popular for big and high-end cars because of high drivability from high torque characteristics. In recent years, smaller cars are also adopting diesel engines due to the development of diesel engine technologies.

iii) Transition of Corporate Average Fuel Economy (CO2 emissions)

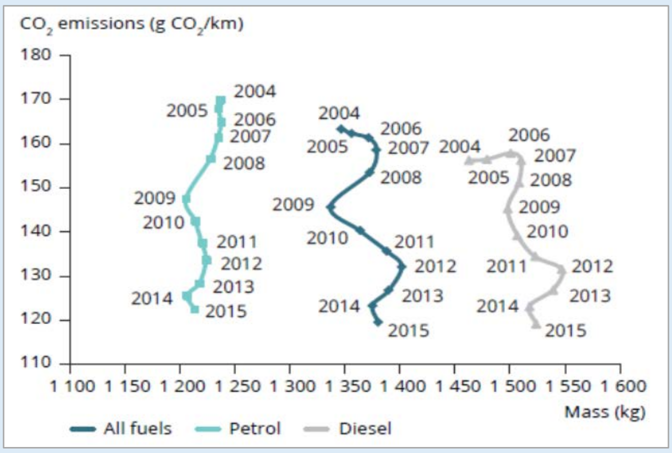
We can overview how emission regulations have impacted companies' average CO2 emissions. Figure 11 shows the transition of corporate average CO2 emissions and vehicle weight. From here, we can see that from 2001 to 2005, the average weight of most companies

Fig. 9 Composition of PLV Powertrain in EU



Source : EEA

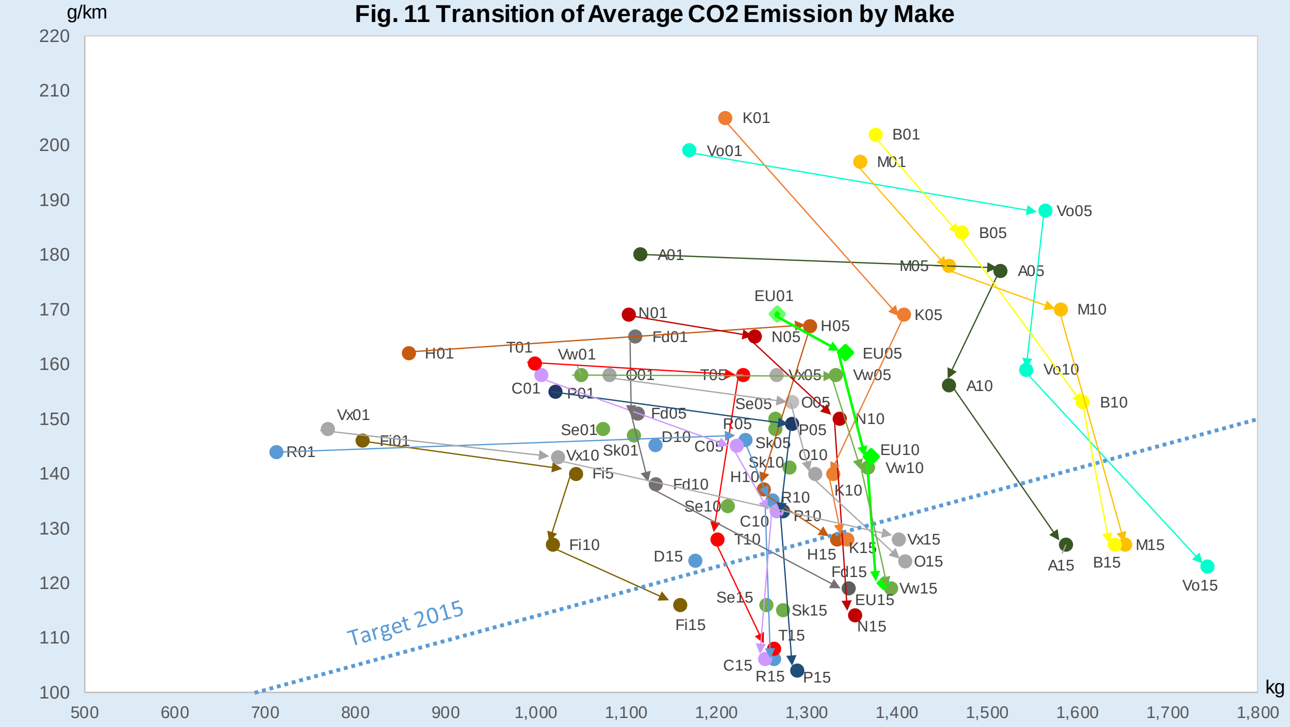
Fig. 10 Average Weight and CO2 Emission by Powertrain



Source: EEA

significantly increased, while average CO2 emissions hardly decreased, or even increased for some companies. From 2005 to 2010, in a reversal, average CO2 emissions were pushed down, while most maintained average vehicle weight. This is supposedly due to the effect of the introduction of a mandatory target in 2008 for 2015, while the initial target issued by EU and ACEA was a voluntary one. In 2015, all of the companies' CO2 emissions were pushed down to meet or exceed the given target.

Fig. 11 Transition of Average CO2 Emission by Make



Note: R:Renault D:Dacia C:Citroen P:Peugeot F:Fiat T: Toyota N: Nissan Vw:Volkswagen Se:Seat Sk:Skoda O:Opel Vx:Vaulxall Fd:Ford H:Hyundai K:Kia A: Audi M:Mercedes-Benz B:BMW Vo:Volvo EU:EU28 01:2001 05:2005 10:2010 15:2015

Source: EEA、ICCT

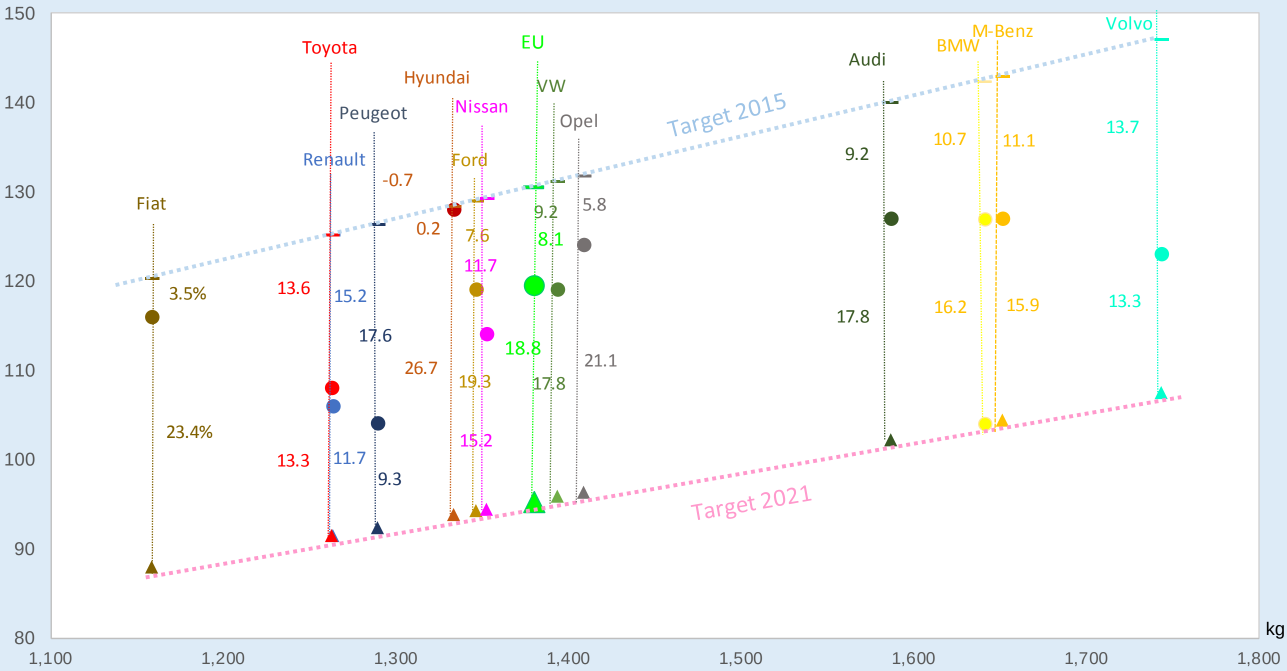
Although the entire EU average met the 2015 target as of 2013, the achievement differs significantly by company(see Figure 12). Companies such as Peugeot Citroen, Renault, Toyota, Nissan, and Volvo far exceeded the target and are already at around the midpoint between the 2015 and 2021 targets. The performance of German premium Mercedes-Benz, BMW, and Audi are reasonable. Fiat, Hyundai, Opel, and Ford seem to have just met the target. Toyota seems to have pushed down its average emissions by the introduction of a sizable number of hybrid vehicles (27% of total sales in 2015), while Renault and Nissan's battery electric vehicles[1] content of about 2% is effective. For premium manufacturers such as Mercedes–Benz, BMW, Audi and Volvo, the effect of plug-in hybrid vehicles seems to be particularly high.

On the other hand, Fiat, whose average vehicle weight is the lightest among all manufacturers and whose proportion of natural gas (CNG) vehicles is high at about 10%, has zero BEV and HEV content. Smaller cars have less room for CO2 reduction from vehicle weight saving, which suggests that they need electrification desperately to reduce CO2 emissions further. Opel and Dacia in the Renault group are similar to Fiat in the sense that both are basically small-car manufacturers and have a low content of electrified vehicles. Both of these companies face the task of reducing CO2 emissions.

---

[1] Electric vehicle those are driven only by battery and motor.

Fig. 12 Distance to 2021 Target by Make



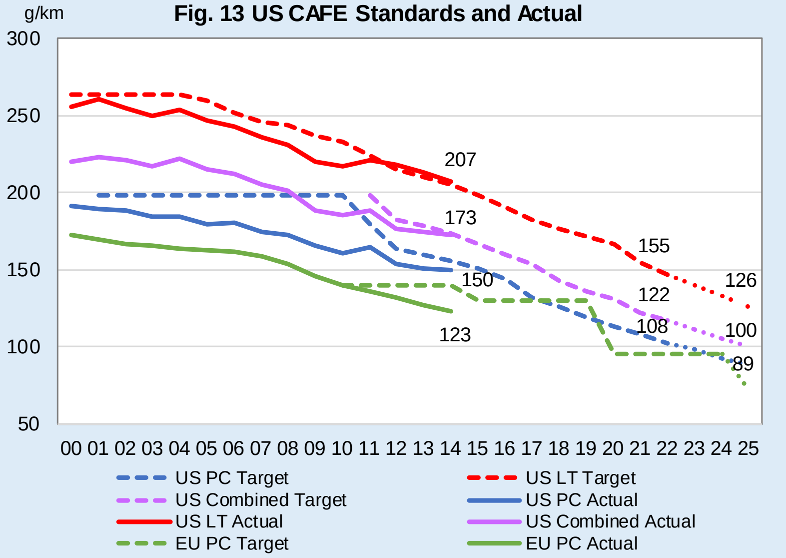
Note: Points represent the average CO2 emission by make. Numbers above the points are the distance from 2015 target and the numbers below points are the distance from 2021 targets.
Source : EEA, ICCT

(2) U.S.

i) Outline of Regulations

The current fuel economy regulations were issued in 2012 by the Obama administration. They applied to the 2017 through 2025 model years (MY) and go into effect in the latter half of 2017. These regulations will be enforced jointly by the National Highway Traffic Safety Traffic Administration (NHTSA) and the Environmental Protection Agency (EPA). NHTSA regulates from a fuel economy perspective, while the EPA's approach is based on CO2 emission restrictions. Although the denomination of the regulation figure is MPG (mile per gallon) for NHTSA and g/km for the EPA, the virtual effect of the two parties' regulation numbers is he same. The uniqueness of US regulations lies in the fact that the classifications of vehicles for target setting is made by vehicle footprint (a multiple of vehicle tread and wheelbase), not by vehicle weight.

Fig. 13 US CAFE Standards and Actual



Note: Numbers for 2014 are actual, target for 2022 and 2025
Source: US EPA/NHTSA

The most distinctive characteristic of US fuel economy regulations is that targets are separately set for passenger cars (PC) and light trucks (LT) (see Figure 13). LT target numbers are approximately 30% higher than PC's (i.e., LT fuel consumption is higher). Although the vehicles are categorized as "trucks", a majority of vehicles included in the category are sports utility vehicles (SUV) and pickup trucks, which are mainly used as passenger vehicles. The average for overall US light vehicle fuel economy is dragged down by the existence of light trucks.

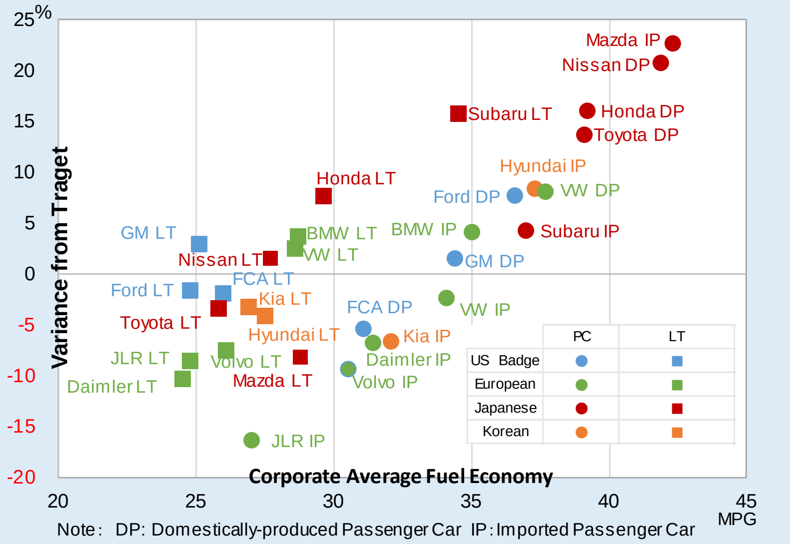
The original reason that LT regulations are laxer is that LTs require more traction than PCs to carry or tow heavier stuff and require higher powered engines. In recent years, however, the cross utility vehicle (CUV), which basically has the same vehicle platform as passenger cars but is categorized as LT, has become predominant in the market. A CUVs' fuel economy can be as good as a PC, which means that in effect these vehicles are given laxer targets by being categorized as LT. As a result, vehicle models such as Volvo's V70 and XC70 are categorized as PC and LT respectively and given different fuel economy targets, although these models are based on the same vehicle platform, thus affecting the product and sales strategy of manufacturers.

Another characteristic of US regulations is that flexibility is allowed on many aspects in meeting targets, such as mutual complementation of target achievement between PC and LT as well as supplementation over the years.

ii) Achievement status by company

Looking at the status of meeting CAFE standards, it varies by PC and LT and by company (see Figure 14). Achievement by company is dispersed for PCs. Japanese companies are mostly well above the targets, while Europeans' achievements are unimpressive. The reason for the difference is that, while Japanese manufacturers are centered on small and medium high-efficiency cars, including hybrid cars, in their lineups, European manufacturers' lineups are biased to larger and low efficiency vehicles in the U.S.

Fig. 14 CAFE Achievement by Make and Product Category (2014 MY)



Note: DP: Domestically-produced Passenger Car IP: Imported Passenger Car
LT: Light Truck Blue: US Maker Green: European Maker Red: Japanese Makers
Orange: Korean Makers
Source: NHTSA

In contract, difference by company for the LT category is relatively small. Among those, European companies such as Daimler, Volvo, and Jaguar Land Rover, and Koreans are behind, while US manufacturers are better off, although their average fuel economy is similar to those of European manufacturers. The background behind this is supposed to be target setting in favor of larger trucks, such as full-size pickups. NHTSA's website post a list of fines paid by manufacturers by missing CAFE targets in the past, all of which are European manufacturers (the list has not been updated in the last few years).

iii) Possible re-examination of CAFE targets

While CAFE targets until 2021 are fixed, targets beyond 2022 are tentative. These numbers were to be reviewed during the 2016 to 2018 period, and are being reviewed by related parties currently (as of March 2017). In conjunction with this, NHTSA and EPA have released the “Mid-Term Evaluation Report”, which assesses the relevance of target settings after 2022. According to the report, the two organizations are in favor of making no changes to the current target numbers. The reasons are: i) Technologies that are necessary to meet targets are available at a lower cost than originally estimated; ii) Targets up to 2025 are attainable by the combination of advanced gasoline engine technologies for the majority of a fleet, introduction of a certain proportion of mild hybrid vehicles and a relatively small number of high-cost electrification vehicles, such as strong hybrid[2] (SHEV), plug-in hybrid (PHEV), and battery electric vehicles (BEV); iii) The auto industry as a whole has made good progress in meeting CAFE targets for the first few years, and some are ahead of schedule.

However, the U.S. automotive industry is calling for the re-examination and relaxation of regulations, and the Trump administration might switch priority from industrial promotion to environmental protection.

iv) ZEV Regulations in California

In the U.S., there are regional regulations on automobile emissions, in addition to federal regulations. California’s Zero Emission Vehicle (ZEV) regulations are the most representative. These regulations are enforced by the California Air Resources Board (CARB). The state of California has a target of converting 100% of car sales in the state to ZEV by 2040 to 2050, and is promoting the diffusion of 1.5 million ZEVs by 2025. For that target, the state has mandated a minimum proportion of ZEV and/or other types of low emission vehicles to companies who sell a certain number of cars in the state.

Fig. 15 Target of Zero Emission Vehicle Sales Proportion to Total Sales Units (%)

Year	Total	ZEV	TZEV+	AT PZEV	PZEV
12	12.0	0.8	2.2	3.0	6.0
13	12.0	0.8	2.2	3.0	6.0
14	12.0	0.8	2.2	3.0	6.0
15	14.0	3.0	3.0	2.0	6.0
16	14.0	3.0	3.0	2.0	6.0
17	14.0	3.0	3.0	2.0	6.0
18	4.5	2.0	2.5	-	-
19	7.0	4.0	3.0	-	-
20	9.5	6.0	3.5	-	-
21	12.0	8.0	4.0	-	-
22	14.5	10.0	4.5	-	-
23	17.0	12.0	5.0	-	-
24	19.5	14.0	5.5	-	-
25	22.0	16.0	6.0	-	-

Note : ZEV : BEV、FCV PZEV : PHEV、HICE AT PZEV : HEV PZEV : CNG and high efficiency engine vehicles

Source : California Air Resources Board

These regulations were initially enforced during the 1990s and have been amended several times. Later in 2017 (from the 2018 model year), the regulations enter a new stage (see Figure 15). Companies subject to the regulations are required to obtain credits by selling a designated number of ZEVs and transitional zero emission vehicles (TZEV, mostly PHEV). In the past, various types of partial zero emission vehicles, including SHEV and compressed natural gas vehicles (CNGV), were granted credits, but from this year on, only BEV, fuel cell vehicles (FCV), PHEV and hydrogen internal combustion engine (HICE) vehicles will be granted credits. If the companies are not able to reach the designated number of credits, they are required to buy credits from others or pay a fine.

---

[2]Hybrid system with high fuel saving effect sold by Toyota Motor and others. “Hybrid System” without notifications usually means this type, and distinguished from “Mild Hybrid System”, which is lower in cost, has simpler mechanism and less effect of fuel saving.

Companies are classified by size under ZEV regulations. Those that are classified as a large vehicle manufacturer (LVM) whose annual number of sales in the state in the last three years average exceeds 20 thousand units) were the Detroit 3 (GM, Ford, and Fiat Chrysler) and the Japanese 3 (Toyota, Honda, and Nissan) until recently. This number increases to ten by adding three German manufacturers (Daimler, BMW, and Volkswagen) and Hyundai Motors from Korea from 2018-MY. JLR, Mazda, Mitsubishi, Subaru, and Volvo are categorized as intermediate vehicle manufacturers (IVM: companies that sold 4,500 to 20,000). IVMs are allowed to earn credits only by TZEV in consideration of their size of operation, while LVMs are not.

In the U.S., there are currently 14 states that are categorized as "Section 177 States", which have chosen to adopt California's rules as their own, and 9 states out of 14 (Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, and Oregon) are applying the regulations with some relaxation. In these fourteen states, which account for nearly 30% of the total U.S. market, sales of ZEVs are mandated from this year on.

With regulatory changes from 2018-MY, carmakers no longer have time to lose in introducing BEV or FCV into these markets, as exemplified in Toyota's announcement that it will accelerate the development of BEVs.

(3) China

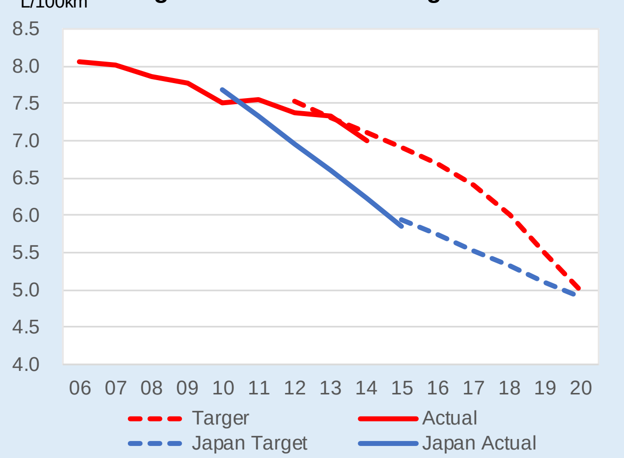
i) Outline of Regulations

Fuel economy regulations were first introduced in China in 2005, which was relatively early for a developing country. The third stage was through 2015, and the fourth stage will last until 2020.

The average fuel economy of all passenger cars sold in China was 7.02 L/100 km in 2015, while the target was 6.9 L/100 km (14.5 km/L), thus the target was missed. The target for 2020 is set at 5.0 L/100 km (20 km/L), which is 37% lower than 2015 and equivalent to a hefty 6.2% per year reduction. This number is similar to that of Japan in the same year, which is 20 km/L (see Figure 16). In addition, in the fourth stage of the regulations, privileged treatment of automatic-transmission cars and SUVs/MPVs was abolished, and severer targets were set for heavier vehicles.

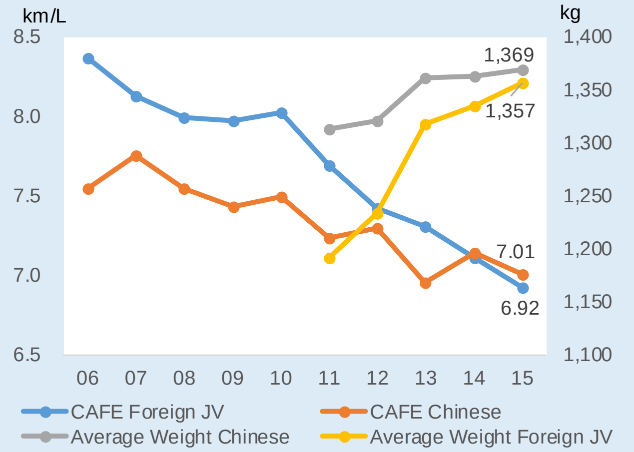
The average fuel economy of all domestically produced cars in 2015 was 6.95 L/100 km. Among those, the average of Chinese-branded cars was 7.01 L/km and foreign-branded cars was 6.92 km/L (see Figure 17). The

Fig. 16 China's CAFE Target



Source: ICCT, MLIT

Fig. 17 CAFE and Average Weight by Ownership



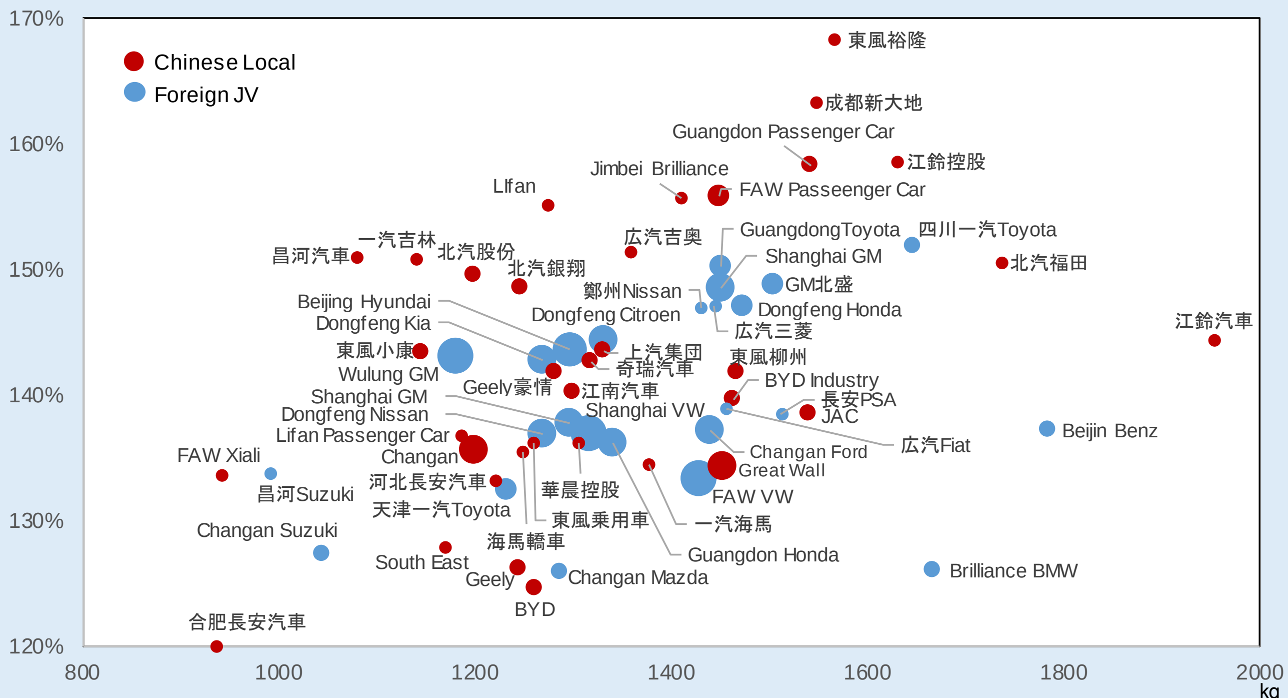
Source: ICET

average of imported cars with a larger size profile was higher at 8.44 L/100 km. In the Chinese car market, demand is shifting to larger cars, such as SUVs, and more luxurious cars with the rise of income level, thus showing signs of the bottoming out of the average fuel economy, particularly for Chinese-branded cars.

ii) Preferential Treatment for New Energy Vehicles

Figure 18 shows how far each manufacturer is from the 2020 fuel economy targets as of 2014. It represents the situation that many small Chinese manufacturers are far from the 2020 targets, while some GM joint ventures are in the similar situation.

Fig. 18 CAFE and Average Weight by Company, and Distance from 2020 Target (2014)



Note: Size of circles inducates the size of companies

Source : ICET

On the other hand, there are some Chinese companies whose divergence from the 2020 targets is relatively small, such as Geely Motors, BYD, and South East (Fujian) Motors. The reason these manufacturers' average fuel economy is low is because a significant number of new energy vehicles (NEVs) are included in their fleet and these vehicles fuel consumption is calculated as zero (for BEV and FCV) or very low (PHEV).

As of 2015, the average fuel consumption of all domestically-produced cars was below target, but it is pushed down by adding NEVs. The average for all domestically-produced cars come down to 6.6 L/100 km from 6.95 L/100 km, while that of Chinese-branded cars sharply drops to 5.82 L/100 km from 7.01 L/100 km. Under the current regulations, the fuel consumption of BEVs is counted as zero and that of PHEVs is set according to electric-drive distance. From 2015 on, the number of NEVs has jumped up due to a generous government subsidy. Geely Auto was the highest in the reduction of fuel consumption due to a high NEV content, which more than halved their average fuel consumption from 6.17 L/100 km to 2.69 km/L. Their average is well below the 2020 target (see Figure 19), and other manufacturers with a high NEV content, such as BYD, South East Auto, and Beijing Auto, have already exceeded the 2020 target level.

However, their average fuel consumption excluding NEVs is high, and they all have missed the 2015 targets if only because of internal combustion engine cars and have shown no improvement in the last two years, which suggests that they have made little improvement in engine technology.

Fig. 19 Effect of CAFE Improvement by NEVs（2015）

Company	CAFE（L/100km）（excluding NEV）		Rate of Improvement (%)
	Excluding NEV	Including NEV	
Geely	6.17	2.69	-56.4
BYD	5.88	3.15	-46.4
BYD Industry	7.98	3.30	-58.6
Jiangnan	7.75	3.95	-49.0
BAIC Motor	6.55	4.39	-33.0
Chery	6.72	5.37	-20.1
SAIC Motor	6.92	4.7	-32.1
JAC	7.01	5.82	-17.0
Linfan Motor	6.52	1.93	-70.4
JMC	9.64	5.46	-43.4

Source: ICET

III. FUTURE PROSPECTS OF AUTO INDUSTRY IN COPING WITH STRENGTHENING FUEL ECONOMY REGULATIONS

In this chapter, we look at the future development of fuel economy regulations and the handling of this issue by the automotive industry.

1. U.S.

NHTSA and the EPA have conducted a joint simulation of the diffusion of fuel economy improvement technologies up to 2025 when current regulations take effect (Figure 20).

Although technologies to be adopted differ by PC and LT, it is projected that gasoline direct injection (GDI), turbo downsizing (TDS), and exhaust gas recirculator (EGR) are widely spread. These technologies are often used in combination, and the estimated proliferation rate in 2025 is over 90% for GDI and 70-80% for TDS and EGR. On the other hand, the adoption of electrification technologies is relatively limited. Mild hybrid (MHEV) [3] technologies are estimated to be used for light trucks at around 40%, but only 20% for passenger cars. Diffusion of strong hybrid (HEV)[4] technology is fairly limited, at 4 to

Fig. 20 Forecast of Fuel Improvement Technology Penetration (US EPA)

Type	Cars		Trucks	
Penetration (%)	2021	2025	2021	2025
TDS 18	43	25	53	19
TDS 24	14	63	16	67
8 speed DCT	61	79	7	9
Cooled EGR	11	65	16	74
HEV	4	4	2	5
BEV	-	3	-	0.3
LRRT2	72	96	74	99
IACC2	71	73	64	55
GDI	60	93	73	97
MHEV	5	20	11	39
Additinal Cost ($/vehicle)	767	1,726	763	2,059

Note: TDS: Turbo Dow nsizing 18: 18 bar 24: 24 bar
DCT: Double Clutch Transmission EGR: Exhaust Gas Recirculator
HEV: Hybrid Electric Vehicle BEV: Battery Electric Vehicle
LRRT2: Low er Rolling Resistance Tyre Level 2 IACC: Improved Accessories Level 2
GDI: Gasoline Direct Injection MHEV: Mild Hybrid Electric Vehicle

Source: Federal Register Vol.77, No. 199, October 15, 2012

[3] The system that uses a small motor for power assist as well as alternator. Fuel saving effect is modest, but the cost of the system is relatively low. Standardization of the specification is in progress in Europe.

[4] High energy saving effect, but the system is complicated and high cost. Is being adopted by limited manufacturers.

5%. The proliferation of BEV is even further limited. Other than powertrains, low rolling resistance tires (LRRT), improved accessories level 2 (IACC2: devices such as super high efficiency air conditioners) and multi-stage double clutch transmission (DCT)[5] are supposed to be widely adopted.

If we look into the adoption rate by manufacturer (see Figure 21), US, European and some Japanese manufacturers' adoption rate of Mild Hybrid (MHEV) is high at 30 to 50%. Adoption rate of HEV is high at Japanese manufacturer such as Toyota but not as high as 20%. As for European manufacturers, adoption rate of BEV and PHEV is relatively high for passenger cars.

Fig. 21 Forecast of Fuel Improvement Technology PenetrationVehicleType and Make（2025）

Penetration (%)	Cars					Trucks					All				
	TDS24	TDS27	HEV	MHEV	PHEV +BEV	TDS24	TDS27	HEV	MHEV	PHEV+BEV	TDS24	TDS27	HEV	MHEV	PHEV +BEV
GM	72	3		22		61	15		50		66	9		35	
Ford	70	4	1	35	2	64	20	28	23		68	9	10	32	1
FCA	72	3		27		69	8	2	47		71	5	1	36	
BMW	60	20	1	49	12	65	19		50		62	20	1	49	9
Daimler	60	12	4	46	17	58	23		50		60	14	3	47	13
Porsche	56	9	2	48	32	61	28		50		57	13	1	49	25
VW	73	2		49	15	69	11		50		72	4		49	12
Geely/Volvo	46	26	5	45	18	72	6		50		54	20	3	47	13
Spyker/Saab	60	8	2	48	21	65	19		50		61	10	1	49	19
Tata/JLR	21	37	13	37	29	59	33	16	34		38	35	15	35	16
Hyundai	75			10		75			50		75			18	
Kia	57			2		75			49		61			12	
Honda	73		3			75			36		73		2	11	
Mazda	75		3	39	2	75		5	37	2	75		3	39	2
Mitsubishi	74		3	47	4	70		7	43	2	73		4	46	3
Nissan	74		1	22		70	9	13	37	2	73	3	4	27	
Subaru	75		10	17	5	75		12	38	5	75		10	22	5
Suzuki	75		16	15	7	75			50		75		13	21	6
Toyota	34	1	16			68	8	3	29		46	4	11	11	
Fleet	63	3	4	20	3	67	11	5	39		64	6	5	26	2

Note: Highlighted areas are those which are forecased over 40% penetration rate. TDS24: Turbo Downsizing 24 bar TDS27: Turbo Downsizing 27 bar
HEV: Hybrid Electric Vehicle MHEV: Mild Hybrid Electric Vehicle PHEV: Plug-in Hybrid Electric Vehicle EV: Electric Vehicle BEV: Battery Electric Vehicle
Source: Federal Register Vol.77, No. 199, October 15, 2012 (by US EPA)

In general, current regulatory targets up to 2025 are supposed to be met by the combination of the sophistication of internal combustion engine technologies, light electrification, and improvement in auxiliary devices. The additional cost of meeting the targets is estimated to be around US$2,000 per vehicle, which is not significant.

As has already been mentioned, in the Mid-Term Report that questioned the validity of the current 2025 regulatory targets, progress in meeting the targets is fair and the cost to meet the targets is projected to be lower than initially estimated, thus there is no need to change the current target numbers. The U.S. automobile market, however, is heading for larger and heavier vehicles due to low interest rates and the price of gasoline. Although the overall fuel consumption of the U.S. fleet is on a decreasing trend, it is not clear whether or not all companies are able to meet the targets, particularly after 2020.

It is also possible that policy guidance on fuel economy improvement under the Obama administration will be rolled back with the Trump administration taking office, in which promotion of the domestic economy and an increase in job opportunities are the first priorities, and investment in infrastructure and deregulation of the

[5] A kind of high efficiency transmission system

energy sector are policy topics. The automotive industry is lobbying for the relaxation of fuel economy improvement targets and that they could be altered.

California's ZEV regulations, on the other hand, will grow increasingly severe. Many carmakers have not yet lined up BEV or PHEV in their lineups. Some are already buying credits from other companies, such as Tesla who is abundant in credits. In the coming years, however, it is apparent such transitional measures will not be stand.

U.S. fuel economy regulations are two faceted; one fairly strict from a global perspective, as in California's ZEV regulations; and the other lax federal CAFE regulations. Such double structure might be a reflection of divided values in society, making the direction of the country unclear.

2. CHINA

China is one of the most active countries in terms of fuel economy regulations. As mentioned, progress in improvement of conventional (internal combustion engine) cars is slow, particularly among Chinese manufacturers, while their cars are growing in size, thus the prospects of the country as a whole are still unknown.

Under such circumstances, the introduction of NEVs is likely to be the key for achieving the proposed target. Differentiated treatment that count one NEV as two or three vehicles is eased year by year; quintupled in 2017, tripled in 2018, doubled in 2019, and single in 2020 and after (see Figure 22). This means that the effect of selling an NEV with average fuel economy is eased every year, while the required range of reduction increases over the years, which makes it harder and harder for companies to meet regulations every year.

Fig. 22 CAFE Target and the Number of NEVs to be Sold (China)

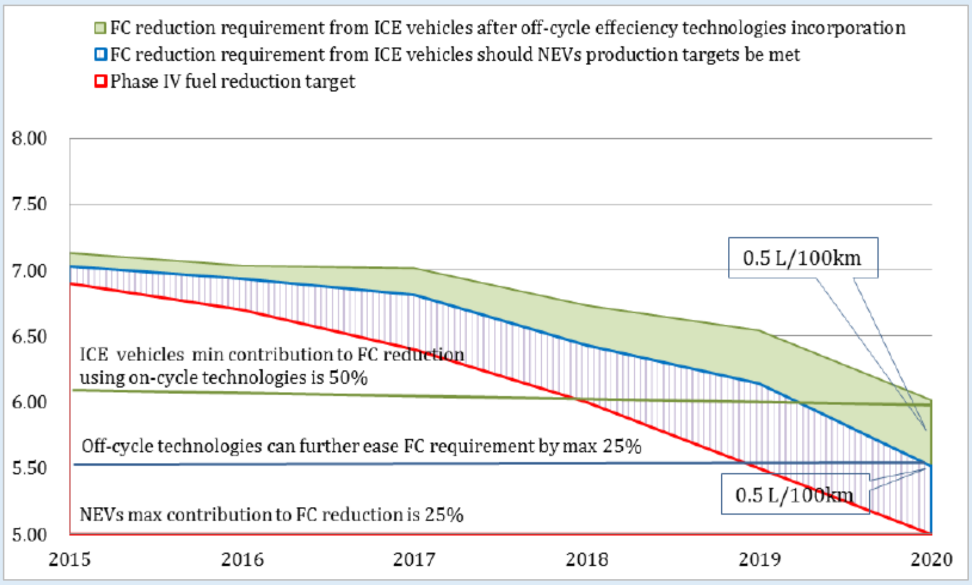
Year	Target (L/100km)	Yearly Change (%)	Multiple for NEV	# of NEV Sold (k)	# of PCs Sold (k)
14	7.12	-2.8	5	*60*	*18,090*
15	6.9	-3.1	5	*140*	*19,530*
16	6.7	-2.9	5	*240*	*21,100*
17	6.4	-4.5	5	*400*	*22,780*
18	6	-6.3	3	*680*	*24,610*
19	5.5	-8.3	2	*1,000*	*28,700*
20	5	-9.2	1	*1,440*	*31,000*
Average		-6.2	Cumulative	*4,000*	*192,410*

Source: Sales number of NEVs are assumptions to achieve CAFE target. Number of passenger cars are forecasts.

Source: ICET

The Chinese government has set a national goal in the Energy Saving and New Energy Vehicle Industry Development Plan (2012 -2020) for building up a production capacity of 2 million NEVs (mostly BEVs and PHEVs) and the cumulative introduction of 5 million NEVs by 2020. The Innovation Center for Energy Transportation, a Chinese think tank, has developed a scenario of achieving the 2020 average fuel economy goal. According to the scenario, about a quarter, or 0.5 L/100 km, of the reduction out of the required 1.9 L/100 km reduction (from 6.9 L/100 km to 5.0 L/100 km) should be achieved by the introduction of NEVs, assuming that 4 out of 5 million NEVs are passenger vehicles, (Figure 23) while the remainder is to be taken care by the improvement of conventional powertrain and off-cycle technologies, such as regeneration brake systems and high efficiency air conditioners. In this scenario, the required improvement of powertrain efficiency goes down to 3.3% per year, which is not much larger than the actual improvement of 2% per year from 2006 and 2014 and is practical to achieve. The Chinese central government provided a maximum of 55,000 yuan subsidy to the manufacturer when an NEV is sold in, and local governments added similar amount. Because of this, production and sales of BEVs skyrocketed in 2015 and 2016.

Fig. 23 NEVs and Energy Saving Technologies Impact on Phase I



Source: ICET

However, there has been frequent occurrence of BEV manufacturers making low-quality products and selling them to related parties to cheat on subsidies. The central government has re-examined and decreased its subsidy in response to this situation. On the other hand, it is presumed that the NEV regulations, a Chinese version of ZEV regulations, will be in place in 2018. Although the details are not clear yet, it is certain that the pressure for the introduction of NEVs will be higher if the regulations go into effect.

As such, the Chinese government's fuel economy regulations and policies are like stepping on the accelerator and brakes at the same time, and it is still unclear whether or not simultaneously pursuing fuel economy improvement and industrial promotion makes sense.

3. EU

(1) Problems of Diesel Engine

Volkswagen (VW)'s "Dieselgate" scandal has severely impacted carmakers' powertrain strategies. As emissions of CO2 and NOx are inversely proportional to each other for internal combustion engines, if they try to improve fuel economy (reduce CO2 emission), NOx emission increases. The scandal has revealed the problem coming from such a trade-off, which has long been hidden from people's eyes.

It has been pointed out that NOx emissions from diesel engines differ significantly between real and test driving. There have been discussions on simulating a test cycle that is closer to reality. Real drive emission (RDE) testing is the new test method that is planned to be introduced around 2020. It is clear that diesel engine emission standards will tighten significantly with the introduction of this test method, and the addition of an SCR (selective catalytic reduction) catalyzer will be required. Such a device costs several thousand euros, and maintenance, such as regular filling of an urea aqueous solution, is necessary. It is not economically feasible

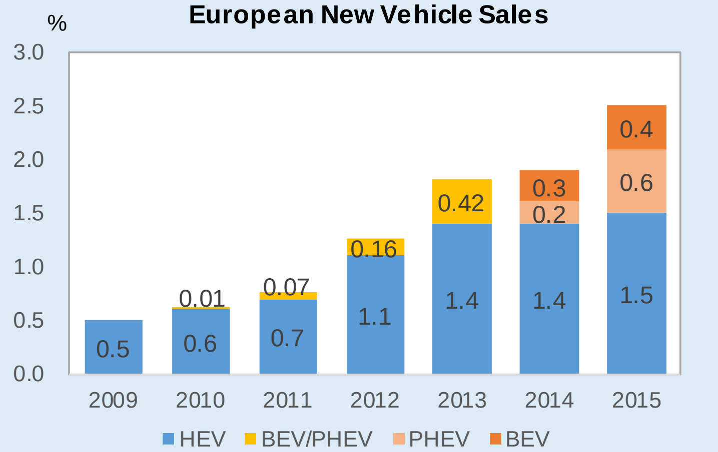
for smaller cars to mount such expensive devices; thus the market share of diesel engine cars is likely to shrink, particularly in the smaller car market.
However, it is not possible or realistic to convert diesel engine cars, which have nearly a 50% share of the market, to gasoline, as that would increase fuel consumption and increase CO2 emissions. That turns the spotlight on electrification.

VW made a major change in their powertrain strategy to aggressively pursue electrification. They are planning to release over 30 electric vehicle models, including BEVs and PHEVs, and push up annual sales of such vehicles to 2 to 3 million units by 2025. Other European manufacturers, such as Mercedes-Benz and BMW, are also putting more emphasis on electrification.

(2) Current Situation of Electrification and Issues

If we overview the situation of electrification in Europe, the proportion of electrified cars of any kind in passenger car sales was 2.5% in 2015, out of which HEVs were 1.5%, PHEVs were 0.6% and BEVs were 0.4% (see Figure 24). Although the share of HEV was less than 1%, and PHEVs and BEVs combined (hereinafter plug-in electric vehicle, or PEVs collectively) had less than a 0.1% share, these have been increasing rapidly in the last few years. The share of PEVs in the EU was higher than in Japan in 2015 (0.5%).

Fig. 24 Proportion of Electrified Vehicles in European New Vehicle Sales



Source : ICCT

The share of PEVs in Europe varies by country. Norway has by far the highest share of PEV sales, which were over 20% in 2015. Second to Norway is the Netherlands, where the share is 10% (see Figure 25). These two countries are outstanding. The share in most of the other countries is less than 1%.

Fig. 25 Sales and Ownership of Electrified Vehicles by Country

Country	Units in 2015	BEV	PHEV	PEV Total (A)	Passenger Car Total (B)	(A)/(B)(%)	Population (in thousands)	Land Area (km2)	GDP per capita
Norway	Sales	25,792	7,819	33,611	150,886	22.3	5,194	322,802	74,822
	Ownership	60,650	10,170	70,820	2,500,000	2.8			
Netherlands	Sales	3,158	41,290	44,448	449,350	9.9	16,933	41,543	43,603
	Ownership	9,370	78,160	87,530	8,000,000	1.1			
France	Sales	17,267	5,520	22,787	1,917,230	1.2	67,063	551,500	37,675
	Ownership	45,170	9,120	54,290	32,244,000	0.2			
Germany	Sales	12,082	11,111	23,193	3,206,042	0.7	81,276	357,121	40,997
	Ownership	30,560	18,670	49,230	43,851,000	0.1			
Japan (for comparison)	Sales	10,356	12,413	22,769	4,215,889	0.5	12,704	377,900	32,486
	Ownership	70,930	55,470	126,400	60,667,517	0.2			

Note 1: BEV: Battery Electric Vehicle PHEV: Plug-in Hybrid Electric Vehicle PEV: Plug-in Electric Vehicle
Note 2: GDP per capita in nominal US dollars
Source: EAFO、IEA、IMF

The reason for the high diffusion rate of PEVs in Norway and the Netherlands is due to generous public support (see Figure 26). For example, in Norway, PEVs are exempt from import duty and value-added tax, while heavy duties and taxes are imposed on poor fuel efficiency gasoline cars. This makes the actual price of PEVs lower than that of gasoline cars. In addition, the cost of ownership and operation is lower due to automobile tax and highway toll exemption for PEVs. As a result, PEV owners receive more economic merit compared with gasoline car owners. It is common in all countries that car owners choose PEVs because they are more economical.

As of today, the cost of a PEV is significantly higher, and it has disadvantages such as the short distance of electric drive and a longer time to charge. Therefore, it is indispensable to reduce the cost and secure merits for users in buying, owning, and using PEVs. In the Netherlands, sales of PHEVs plunged after the elimination of tax exemption for company-owned cars.

Fig.26 Incentives for Electrified Vehicles in European Countries

Type of Incentive	Norway	Netherlands	France	Germany
Purchase Subsidy	Import duty exemption	Exemption from registration fee.　Reduction for PHEV according to CO2 emission.	Purchase subsidy by CO2 emission (€6,500 for less than 20g/km, €1,000 for 20 - 60g/km）	BEV：€4,000 and HEV：€3,000 for vehicle value less than €60,000) (up to 400,000 units, federal budget 600 million euro, until 2020)
	VAT (25%) exemption		Additional subsidy to replace over 10 years old diesel cars (€4,000 for BEV, €2,500 for PHEV)	
Financial Support for Ownership	Road Tax (yearly) exemption	Road tax exemption	Road Tax Exemption/reduction	Auto tax exemption for the first 5 years BEV registeredon to Dec 31, 2020
	Reduction of corporate tax (50%)	Reduction of road tax for PHEV (50%)	Corporate auto tax exemption（BEV：unlimited, HEV：first 2 years）	Tax deduction for company owned BEV
	Reduction of VAT on lease fee (25%)	Income tax deduction for company cars		
		Decution of income tax for PEVs and charging infrastructure		
Preferntial Treatment during Use	Exemptin of road toll and ferry fee			Free/dedicated parking for BEV, Use of bus lane (by city)
	PEVs are allowed to drive bus lane			

Source: European Alternative Fuel Observatory

A persistent problem is the short cruising distance of BEVs due to the low energy density of batteries. The cost of batteries is said to have decreased to half or a quarter of the level in 2010, when many BEVs were put on the market, as well vehicle cost accordingly. On the other hand, the capacity of car mounted batteries has not increased much. In the case of the Nissan Leaf, it started with a 24 kWh battery and later added a 30 kWh version. Cruising distance per charge has increased from 200 km to nearly 300 km, but the energy contained in the battery is equivalent to about 3 liters of gasoline. This results in the high efficiency of the electric drive, but it also means that cruising distance can be undercut easily by the use of energy for air-conditioning. The battery of the Leaf is supposed to weigh over 200 kg, and it is unlikely that batteries would be added without increasing the size of its body.

Unlike BEVs, cruising distance is not a big issue for PHEVs. A PHEV’s problem is the high cost and physical size requirement of having an internal combustion engine and electric drive system in a vehicle. For that reason, the PHEV system is mainly being applied to expensive and middle-end or high-end cars.

As overviewed, pressure toward electrification is increasing in conjunction with a forecasted decline in diesel cars. Carmakers are aggressively planning to bring in electrified vehicles. The wall is high for the mass introduction of BEVs in the small car segment, due to remaining limitations, while there is likely to be a certain proliferation of PHEVs in the middle and upper segments. Providing economic merit for the users of BEVs, such as a generous subsidy or tax exemption, are vital in order to promote the diffusion of small BEVs, as is the development of use cases such as a second car or for car sharing that minimize the demerits of BEVs.

IV. CONCLUSION

1. DIFFERENCE IN FUTURE DIRECTION BY COUNTRY AND REGION

As reviewed, fuel economy regulations are taking effect in more and more countries and will be strengthened globally in the long term. The strictness of regulations and the readiness of carmakers differ by country and region.

In the U.S., the majority of light vehicles are relatively larger compared with other regions, and the improvement of combustion engine technology and mild hybrid technology would be a major means of fuel economy improvement. In some states, such as California, BEVs might be introduced to a certain degree to meet the tightening ZEV regulations. But the U.S. car market has a deep-rooted orientation to larger vehicles. Therefore the proliferation of BEVs and PHEVs is likely to be limited.

In Europe, carmakers seem to be trying to meet the 2021 targets by a combination of mild hybrid technology as the base, BEVs for a small segment, and hybrid technology, including PHEVs, for the larger segment. However, to meet the projected target of 68 to 78 g/km in the next stage of regulations after 2025, they may need to convert all vehicles to PHEVs or an equivalent. Considering that converting small cars to PHEVs is not realistic, a significant portion have to be replaced by BEVs. As already mentioned, however, BEVs have not yet resolved the problem of cruising distance and price. If carmakers were to raise the proportion of BEVs and PHEVs to 20-30% of their sales, strong promotional policies by the government, such as in Norway, are required across the region. In addition, it is necessary to dispel people's perception that a car should cruise for 400 to 500 kilometers once it is fully charged.

The situation in China is more difficult. In only three years, carmakers are required to achieve significant improvement, while there has been little progress on improving internal combustion engine technology. Without hybrid technologies, they will need to introduce a significant number of BEVs and PHEVs, but government subsidies are being cutting back. The proliferation of cars in China is still low, at one per ten people. In order to diffuse a large number of BEVs, they need to provide entry users with appealing choices, such as good functions, high quality, and competitive price over conventional gasoline engine vehicles. More specifically, the cost of a vehicle has to be less than 100,000 yuan, with cruising distance of 200 km or less. If such a concept is attainable, BEVs could be widely accepted as entry cars, because first-time buyers do not have fixed concepts about cars. As for developing countries other than China, they rely technologically on the manufacturers of advanced countries and do not have financial support to have electrified vehicles accepted by the market.

We did not touch on the situation in Japan. With the current market breakdown of nearly 40% mini-cars, 20% hybrid cars, and 20% other, there seems to be no problem in meeting the immediate targets for 2020. However, stronger initiatives to introduce BEVs and PHEVs, in addition to HEVs, will be necessary.

As such, the direction is significantly different between the U.S. and Europe, among advanced countries. Among developing countries, the situation varies; China is heading for electrification, with the intent of industrial promotion by generous government financial support, Russia has little incentive to improve fuel economy with abundant energy resources, and lower-developing countries may not have money or technology to promote fuel economy improvement. Progress and the direction of fuel economy improvement is different by country and region and unlikely to converge into one.

2. DIRECTION BY COMPANY

There are two major streams in the direction that company's are taking to meet regulations on strengthening fuel economy. Toyota Motor developed and introduced the hybrid system about 20 years ago and consistently has led the market since then. The company now has a majority share of the world's hybrid vehicle market. On the other hand, while the hybrid vehicle market share in Japan has risen to around 20% in Japan, it is insignificant in other markets. There are not many hybrid vehicles being sold by manufacturers other than Toyota and Honda. Hybrid technology is not universal. One reason for this is that the technology is a highly sophisticated one that coordinates an internal combustion engine and an electric drive system, the other is that Toyota has retained the technology to maintain the competitiveness of their cars and has not provided the technology to others widely.

The other stream is formed by a group of European countries who have focused on the sophistication of internal combustion technologies, such as clean diesel and turbo downsizing. They lag in electrification technologies, on the other hand. VW's diesel-gate scandal, under such circumstance, has overshadowed the future of diesel technology. Its application could be more limited than has been expected, particularly for smaller cars. While medium and large-sized cars are likely to continue to use diesel technology, and be HEVs and PHEVs as well, soon, and to a large extent, smaller cars are likely to be required to be BEVs. Mass diffusion of BEVs at current cost performance and market circumstances is unlikely, and thus the prospects are not good for meeting fuel economy regulations after 2021.

Neither of these two group of companies have yet to draw a clear scenario of meeting tightening fuel economy regulations in the long run.

TO CLOSE

Fuel economy regulations are tuned to the social environment, economic situation, and industrial policy unique to each country and region. Although the need to deter global warming is shared globally, in practice there are social costs that must be faced.

The most visible one is the increase in the use of automobiles. It is not easy to convince users to accept the additional cost of electrified vehicles without offsetting additional value. If the public sector were to bear the additional cost, it would have to be funded through taxes. In order to effect government funding in a democratic system, voter support is required, as a matter of course. In order to achieve mass introduction of electrified vehicles, the amount of government funding would pile up and make it difficult to gain popular support.

In Norway, BEVs are allowed to drive in bus lanes to avoid congestion. As the number of BEVs increases and more BEVs drive in bus lanes, they tend to disturb the smooth passage of buses, and thus the arrangement is under re-examination.

Controversy about policies exists in the U.S. as well. As mentioned earlier, carmakers are reported to be lobbying for the re-examination of current fuel economy regulations to take advantage of the anti-environmental Trump administration. The administration might make considerations to U.S. carmakers who are struggling to meet regulations.

In the end, fuel economy regulations cannot progress beyond the costs that the society can afford. Regulations should strike a balance between the target to be attained and that which it is possible to attain, in addition to the correctness of the direction. For the players, consistent effort to achieve a given target at the lowest cost is required.

Fuel economy regulations, in the short term, target the reduction of energy consumption and CO2 emissions, while in the longer term, they ultimate lead to the elimination of the consumption of fossil fuels and CO2emissions. Contemplating the way to achieve that goal induces us to re-examine the physical form, function, and role of the automobile in society.