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ALTERNATIVE POWERTRAIN STRATEGIES AND FLEET TURNOVER IN THE 21ST CENTURY

BRUCE M. BELZOWSKI
WALTER MCMANUS

UMTRI
UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE

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Bruce M. Belzowski
Walter McManus

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

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16. Abstract

The changes taking place in the global automotive industry related to alternative powertrains and fuels are affecting each country or region differently. Each country or region has its own policies in place to monitor and manage vehicle fuel consumption and emissions. Countries or regions also have different numbers of new vehicles sold annually and the total numbers of vehicles in their fleets. This analysis looks at the current and future direction of alternative powertrains/fuels across four developed economies (United States, Western Europe, Japan, and South Korea) and four developing economies (Brazil, Russia, India, and China) in order to measure the impact of increasing the number of alternative powertrains/fuels in their fleets. In particular, the analysis looks at the how much of each country's fleet will turn over to vehicles based only on alternative powertrains/fuels by 2050 by introducing three different alternative powertrain/fuel models (*less aggressive*, *moderately aggressive*, and *very aggressive*). A *less aggressive* approach will yield fleet turnover rates of 60 percent or more for most countries, a *moderately aggressive* approach will yield fleet turnover rates of over 80 percent for most countries, and a *very aggressive* approach will yield fleet turnover rates of nearly 90 percent or more for most countries.

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Introduction

In the United States, the terrorist attacks of September 11, 2001, not only initiated the "War on Terror," they also initiated the "War on Oil Dependence." By 2008, President Bush asserted that the United States was "addicted to oil."[1] United States policy since then has slowly but surely tried to move the country in the direction other countries throughout the world had moved to decades earlier. Through government policies, particularly those that raised fuel taxes dramatically and more recently those that try to control greenhouse gas emissions (GHG), most developed economies and some developing economies set the direction of vehicle and powertrain design, and especially consumer expectations about the types of vehicles that reduced their countries' dependence on foreign oil.

The United States and more recently China were anomalies in their countries' control of fuel prices. The United States tried to move in the direction of fuel-efficient vehicles during the oil shortages of the 1970s, but when the price of oil stabilized in the late 1980s and 1990s, so too did United States fuel economy regulations. It was not until the terrorist attacks on September 11, 2001 that the United States government truly began to publicly admit that its main sources of oil came from areas of the world that may not always be reliable partners.[2]

Taking action to reduce United States dependence on foreign oil became a rallying cry of both political parties even though it might also harm United States oil companies. The key element that the government and the oil companies always understood, but were reluctant to admit publicly, was the time it would take to migrate the country away from its dependence on foreign oil. The central questions this report addresses are: If the goal is to reduce dependence on oil, which means the elimination of gasoline- and diesel-fueled engines, then how long will it take to turn over a country's fleet of vehicles to alternative powertrains/fuels? And on a global scale: What paths will individual countries take to more fuel-efficient fleets?

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[1] Admittedly, President Bush probably meant that the U.S. was addicted to "foreign" oil. His plan did not include eliminating U.S. oil production, but increasing U.S. production through Alaskan and offshore drilling.

[2] The oil embargos and the hostage crisis in Iran in the 1970s certainly made both the government and the U.S. population aware of the instability of the region, but it did not influence sustained government action to reduce U.S. dependence on foreign oil when oil prices stabilized. It may be that a long-term movement away from a reliance on oil might hurt U.S. oil companies as well as foreign companies, but even that argument lost favor after the September 11 attacks.

In this report we will review the regulatory and technology trends related to fuel economy and emissions for four developed economies—the United States, Western Europe, Japan, and South Korea—and four developing economies—Brazil, Russia, India, and China. We will focus on the contrasts between the United States, which has for so long had a unique vehicle fleet, and the rest of the world. We will also examine the challenges automotive companies face as they try to meet the needs of governments across the globe, including managing differing and changing regulatory environments, profiting from and migrating customers to the new technologies, and staffing their companies to compete in the new powertrain environment.

The Global Overview

To get a better understanding of the scope of the global automotive fleet, one must see how major developed and developing economies differ in their automotive fleets. For example, population size represents the opportunity manufacturers see in any particular country. Figure 1 shows that from the sheer population numbers, China and India are the major countries with the most potential vehicle buyers.

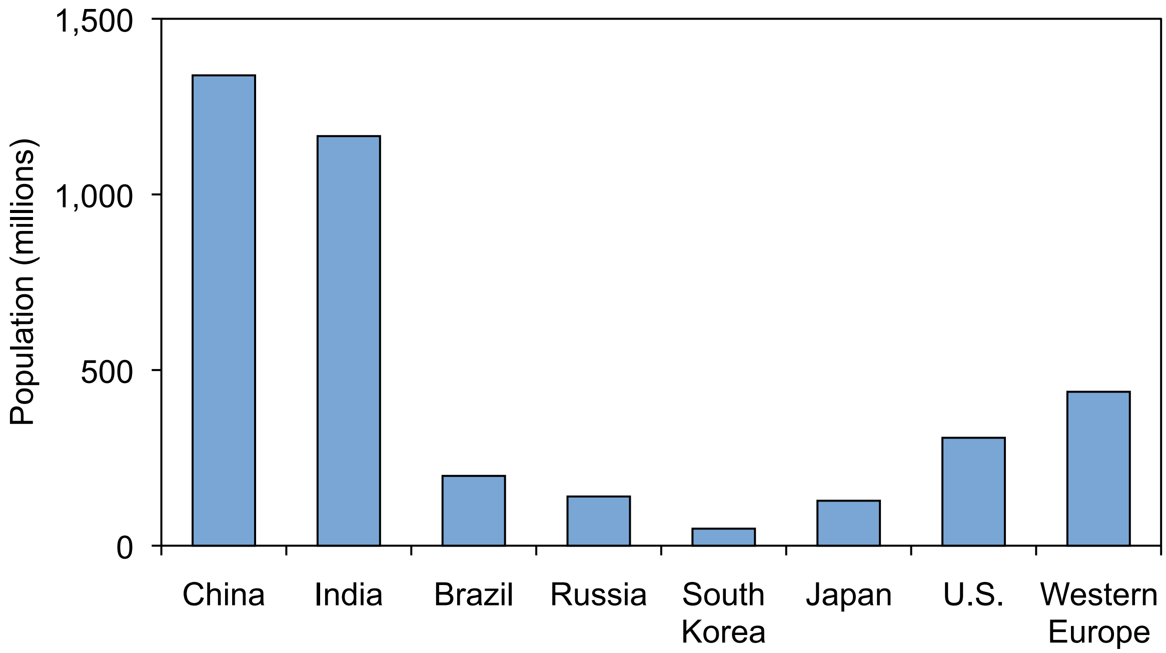

Figure 1. Country populations (Ward's Automotive Group, 2010).

Persons per vehicle in Figure 2 shows that considering the number of people and the number of vehicles per country, China and India again show the most promise as markets for new vehicles, with China reporting 30 persons per vehicle and India reporting nearly 80 persons per vehicle. By taking China and India out of Figure 3, one can see how relatively saturated markets such as the United States, Western Europe, and Japan are, with less than two persons for each vehicle in the country.

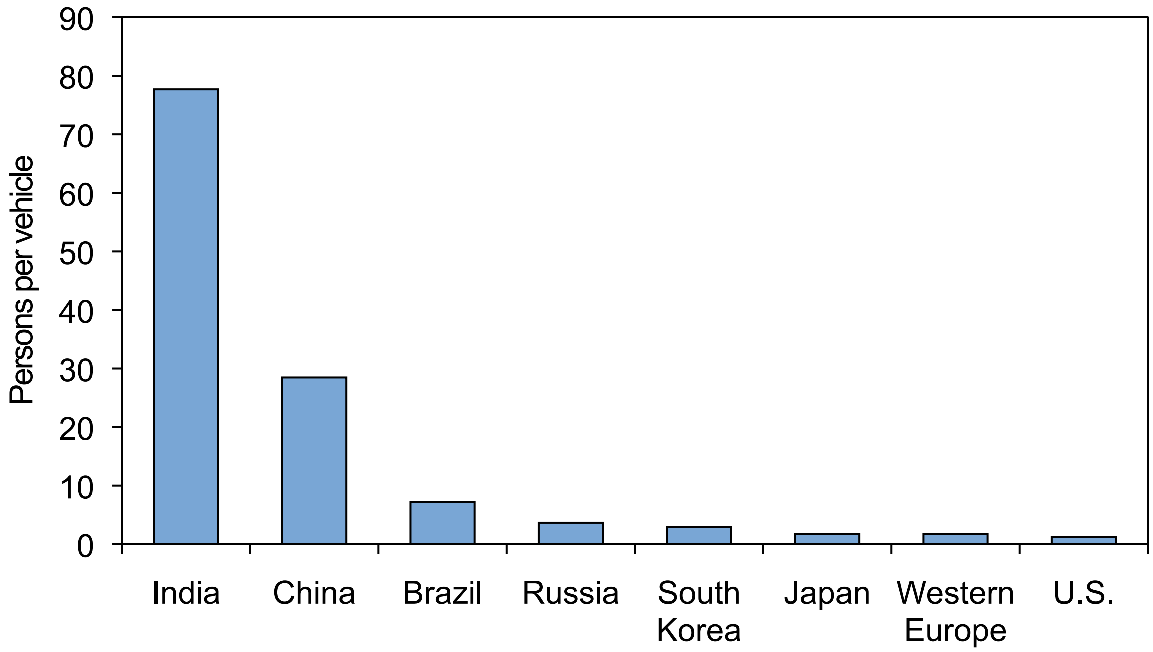

Figure 2. Persons per vehicle (Ward's Automotive Group, 2010).

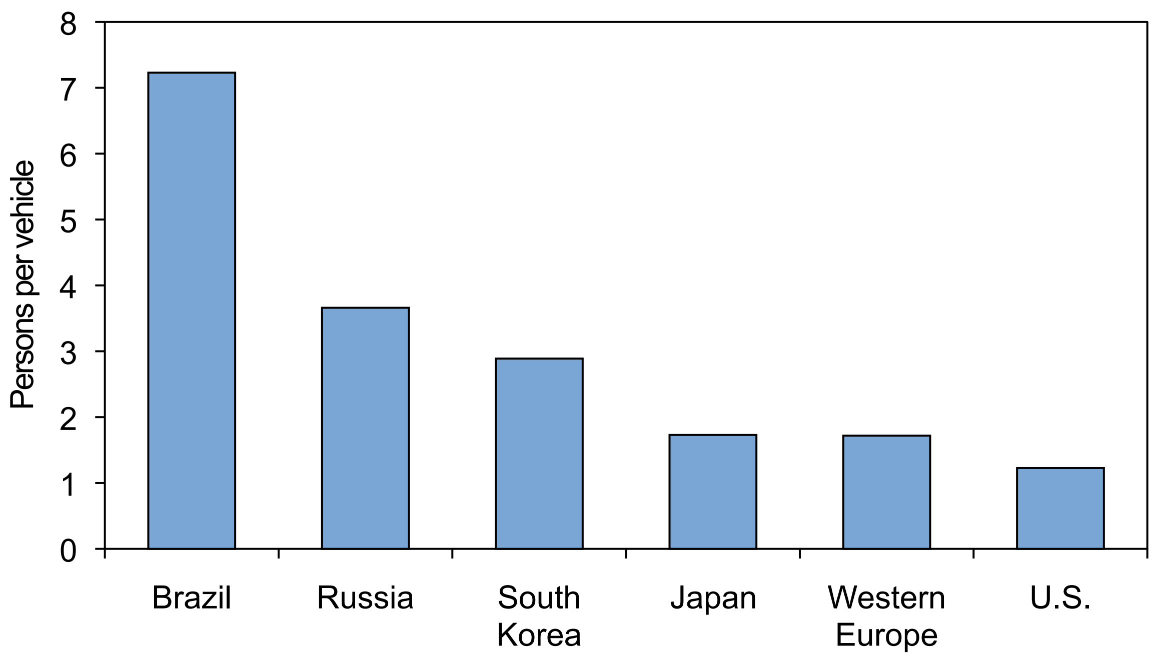

Figure 3. Persons per vehicle, minus China and India (Ward's Automotive Group, 2010).

Another way of looking at the challenge of turning over a fleet is through the total number of vehicles in operation, as seen in Figure 4. Western Europe and the United States are far and away the countries/regions with the largest number of vehicles in their fleets. Taking the United States and Western Europe out of the graph, as in Figure 5, shows large numbers of vehicles that make up the fleets of Japan, Russian, China, and Brazil.

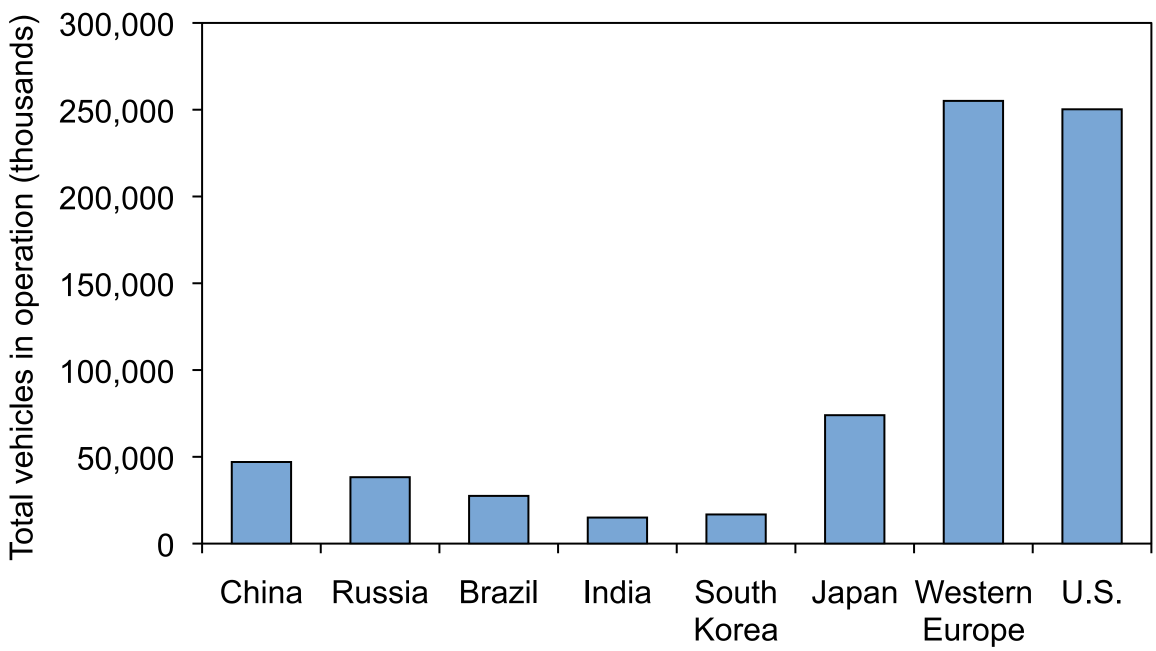

Figure 4. Total vehicles in operation (Ward's Automotive Group, 2010).

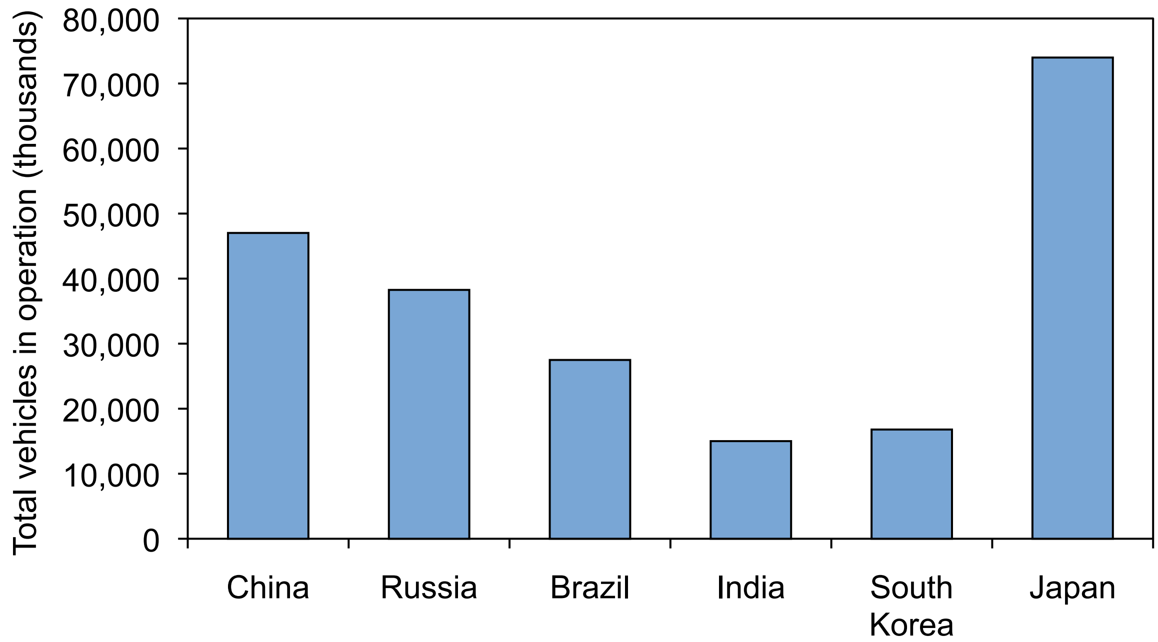

Figure 5. Total vehicles in operation, minus Western Europe and the United States (Ward's Automotive Group, 2010).

Viewing the vehicles in operation for our target countries by looking at the distribution of passenger cars (including light trucks) and commercial vehicles, as shown in Figure 6, provides another perspective on a country's fleet. A marked discrepancy is seen between the United States and China relative to other countries where commercial vehicles make up a large number of the vehicles in operation in their countries. The discrepancy is especially noticeable when making comparisons with the fleets of Western Europe, Japan, and Russia where commercial vehicles represent a small portion of the vehicles in operation.

Taking the United States and Western Europe out of the graph, as shown in Figure 7, shows China's focus on commercial vehicles relative to passenger cars, the nearly even number of passenger cars and commercial vehicles in operation in India, and the discrepancy between passenger cars and commercial vehicles in Japan.

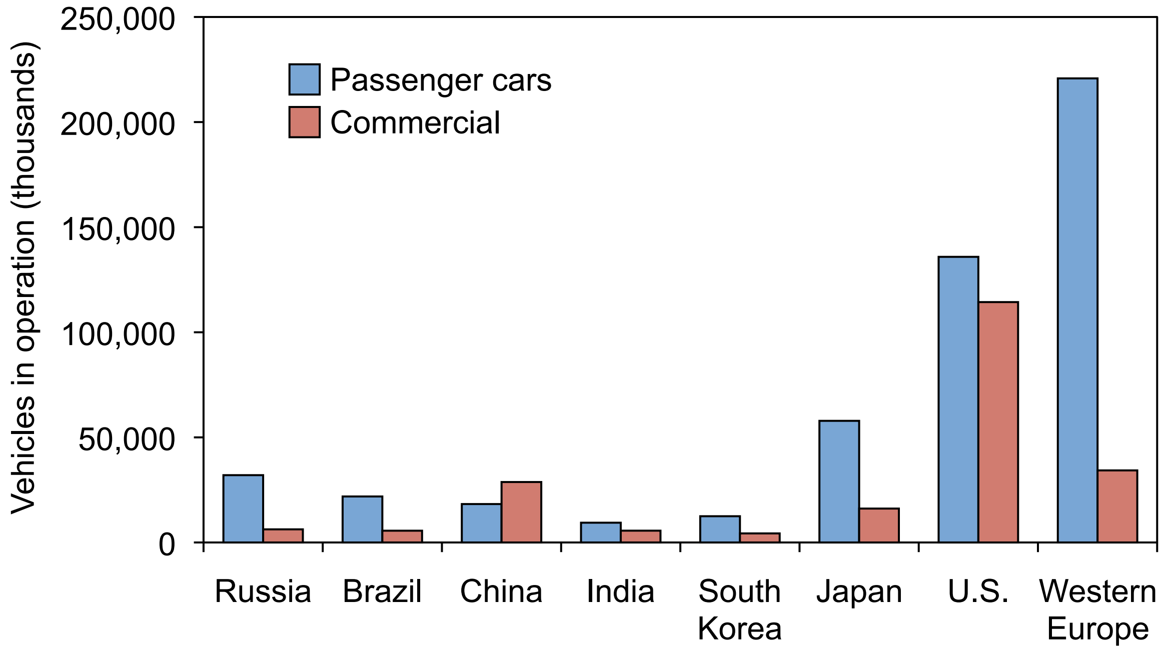

Figure 6. Total vehicles in operation (passenger cars and commercial vehicles) (Ward's Automotive Group, 2010).

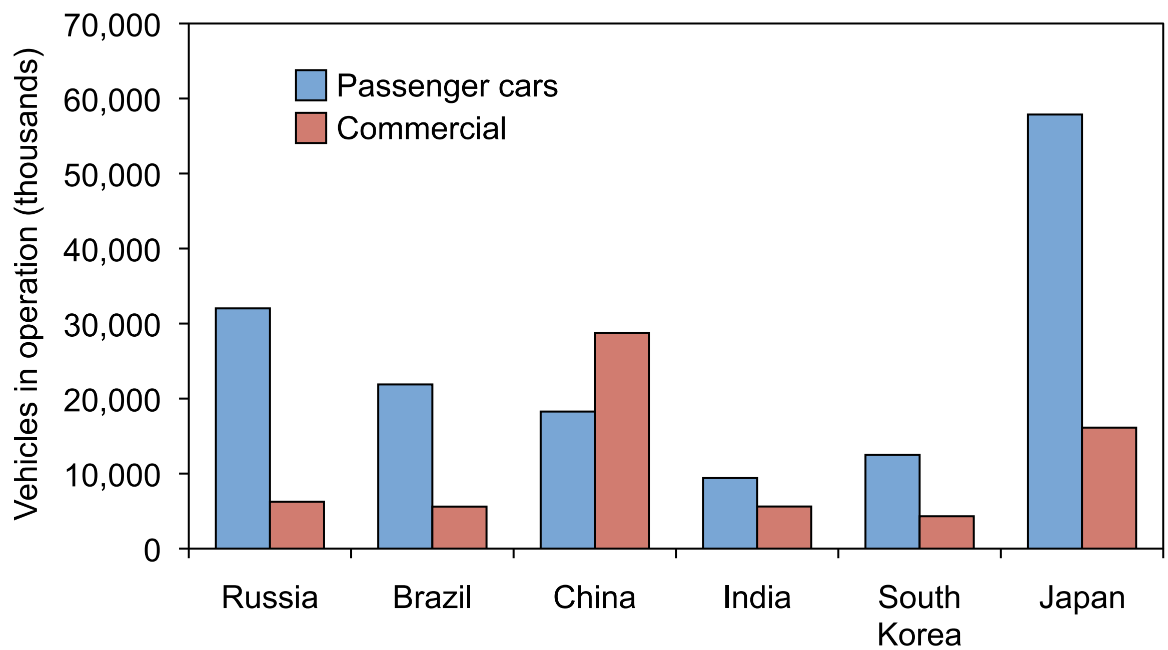

Figure 7. Total vehicles in operation (passenger cars and commercial vehicles), minus Western Europe and the United States (Ward's Automotive Group, 2010).

The issue of the number of commercial vehicles versus the number of light vehicles (passenger cars and light trucks) plays out in an analysis of the number of persons per light vehicles versus the number of persons per total vehicles, as shown in Figure 8. Excluding the commercial vehicles from the analysis provides a very different picture of the number of potential light-vehicle buyers, particularly in India and China, where there are about 100 and 125 persons per light vehicle, respectively.

Taking China and India out of the graph, as shown in Figure 9, shows little difference between the number of persons per car and per vehicle, reflecting either the large number of light vehicles that make up each country's fleet or China's focus on commercial vehicles relative to passenger cars, the nearly even number of passenger cars and commercial vehicles in operation in India, and the discrepancy between passenger cars and commercial vehicles in Japan. The larger number of passenger cars in Japan is in contrast to its vehicles per capita, which is nearly eight persons per vehicle (third behind China and India). Thus, compared to other countries (excluding the United States and Western Europe), Japan has many passenger cars in operation despite the high number of persons per vehicle.

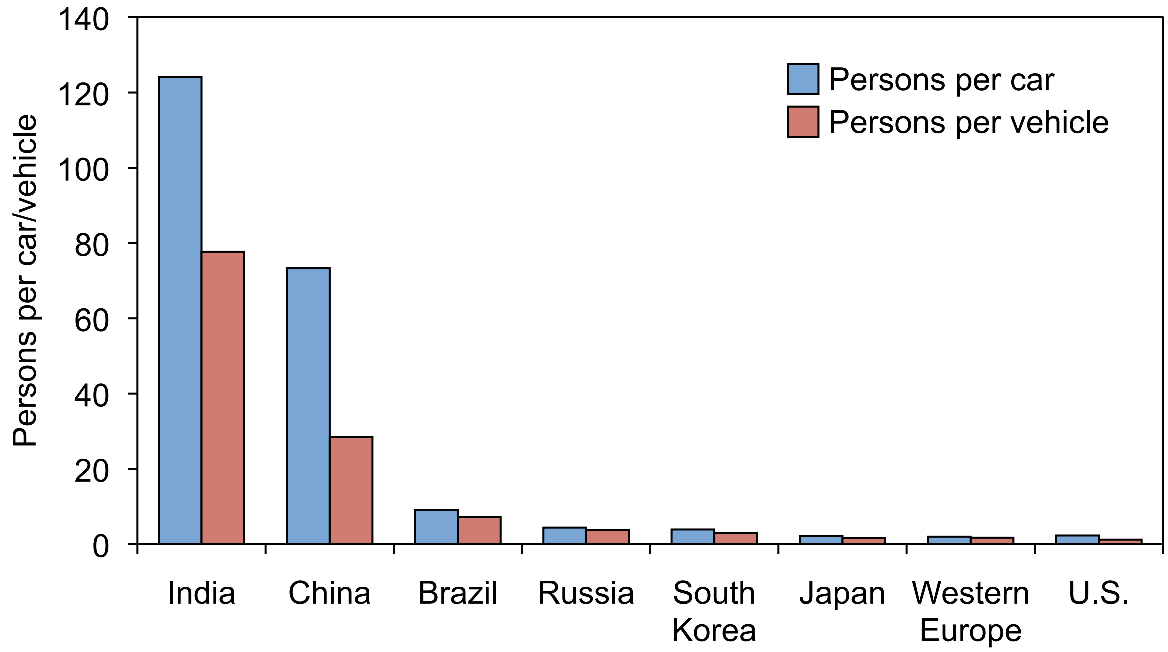

Figure 8. Persons per light vehicle compared to persons per all vehicles (light and commercial vehicles) (Ward's Automotive Group, 2010).

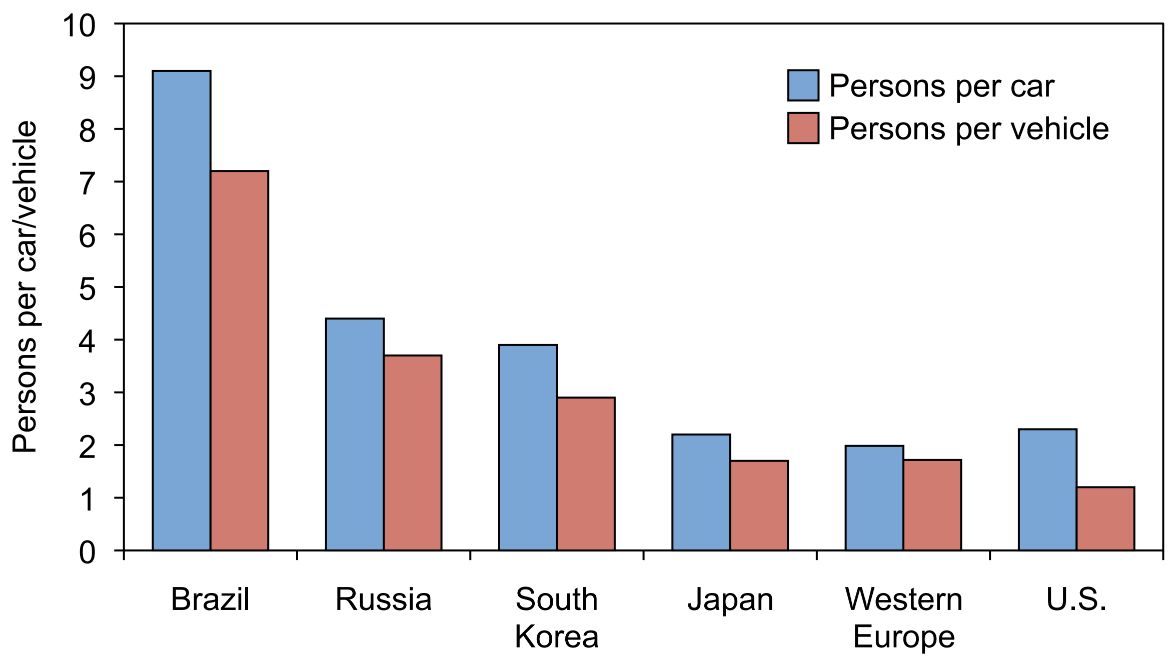

Figure 9. Persons per light vehicle compared to persons per all vehicles (light and commercial vehicles), minus China and India (Ward's Automotive Group, 2010).

Global Efforts Aimed at Alternative Powertrains and Fuels

When transitioning a country's fleet of vehicles to one that allows the country to be less dependent on foreign oil through more fuel-efficient vehicles, while at the same time reducing GHG emissions, each country has its own particular challenges. It may have to turn over a large fleet of vehicles as the United States must do, while also psychologically migrating customer expectations and demand towards more fuel-efficient vehicles. All other developed economies have already migrated customer expectations toward vehicles that provide better fuel economy through higher fuel prices driven by increases in fuel taxes. Other countries may use their natural resources to provide new fuels to lessen dependence on foreign oil, or they may try to develop leapfrog technologies to speed up the long process of transitioning away from oil-based fuels.

Government Efforts

Some governments try to manage this transition through regulations and support of development of new technologies that support the twin goals of increased fuel economy (thus reducing dependence on foreign oil) and reduced GHG emissions. Governments may also focus on development of technological advances through their support for research and development of new powertrain technologies at national laboratories. Because the technologies are so new, one could call them alternatives because there is no one technology that is receiving support; rather, multiple technologies are receiving support. These alternatives include a variety of different types of hybrid vehicles that combine electric drive with a gas (diesel) engine. There are mild hybrids, full hybrids, plug-in hybrids, hydraulic hybrids, and diesel hybrids. Some of these are intended solely for the light-vehicle market (passenger cars, light trucks, and SUVs), while others are intended for the medium- and heavy-duty truck market. There is also development taking place in the all electric and fuel cell areas. Much funding is being put into the development of batteries that will allow vehicles to move completely away from oil-based fuels.

There is also government-supported work being done in the area of new fuels. Diesel fuel is more efficient than gasoline from a fuel economy perspective, thus reducing dependence on foreign oil, but it has significant cost and emissions challenges.[3] Ethanol, an alcohol-based fuel, originally showed promise because it was produced from corn, but it took less than one year after its introduction into the fuel stream in the form of E85 (85 percent alcohol and 15 percent gasoline) for the price of all corn-related foods to begin to rise and douse the enthusiasm for E85.[4] E85 is still produced, but in much lower volumes than originally predicted, though some countries such as Brazil developed their whole automotive industry around E85 based upon sugar cane. Other governments and industry are researching other ways to generate E85 and other biofuels ranging from switchgrass to garbage. Though E85 has not been completely abandoned, it became an example of unintended consequences of governmental policies. It also showed how difficult it is to predict winners and losers when it comes to technologies or fuels that are not yet fully developed.

Though governments are putting considerable effort into regulations and supporting the development of new powertrain technologies, the final major transition that needs to be made is in the mind of the consumer. Consumers will decide how they spend their money on vehicles. If governments want to seriously change the fuel efficiency and emissions of the vehicle fleet, they must convince consumers to purchase the vehicles that provide these benefits. To that end, governments are making the case that consumers will always have a choice, but that choice will be based on vehicles that meet government regulations.

Governments have a number of levers they can pull to evolve consumer attitudes and shape future demand. These efforts not only set the technological stage but also the psychological stage that will affect consumer behavior.

- *Industry Regulations*: Regulations that directly affect manufacturers indirectly affect consumer choice.
- *Communication*: A president or prime minister has the bully pulpit to continually stress the importance of the transition to more fuel-efficient and less polluting vehicles.
- *Direct Consumer Support*: Tax rebates for purchasing vehicles with new fuel-efficient technology provide one way of supporting and promoting new technology. Also, the

[3] Europeans have a different view of diesel, which will be discussed in the Western Europe section.

[4] Unfortunately many entrepreneurs built ethanol plants in corn-growing states, and many of these plants have now closed or are not producing the expected profits.

introduction of "Cash for Clunkers" programs show the public a government's willingness to directly support its goals.

- *Fuel Pricing Policies*: Though most countries already use fuel taxes as a method to force buyers to purchase vehicles that are more fuel-efficient, in some countries there is no willingness to support increased taxes on fuel in the legislature. But there are other methods, such as long-term, incremental, fuel-price increases, that provide an expected, gradual increase in fuel prices and may appeal to legislators if circumstances dictate a need for a more immediate change in consumer behavior.

Finally, local governments can also play a role in the transition to technologies that are more fuel efficient and emit fewer emissions. By providing research and development incentives for companies to locate in their locale, local governments are encouraging and supporting the development of these technologies, and also increasing the level of knowledge workers within their locale. Universities are also recognizing the importance and opportunities that the development of these new technologies can provide for their faculty and students. Many are reorienting their programs to apply for government research and development funds in this area.

Manufacturer and Supplier Efforts

Global manufacturers and suppliers have also taken up the challenge of developing new powertrain technologies. In the U.S., for example, when the Bush administration announced at the end of 2007 that it would increase CAFE standards by 40 percent by 2020, the manufacturers quickly put together plans for introducing more fuel-efficient vehicles into their fleets. By January 2008 at the Detroit International Auto Show, all the manufacturers were showing how they would meet the CAFE goals, with each manufacturer presenting a different strategy to meet the goals.

Companies are bringing more small vehicles into their fleets[5], considering new materials for decreasing the weight of vehicles, and researching different powertrains to find the appropriate technologies that will allow them to meet current and future global regulations. Some of the powertrain technologies are improvements of current powertrains, while others

[5] In fact, moving to smaller, more fuel-efficient vehicles will provide U.S. manufacturers larger economies of scale as the vehicle platforms used in the U.S. become more similar to the vehicle platforms they use throughout the rest of the world.

require a paradigm shift of consumer behavior and energy infrastructure. What is unclear is which technology will dominate in the future. However, there is a hierarchy of powertrain technology strategy based on the technological challenges each presents.

- *Improving the internal combustion engine*: All companies are working to improve the technology that represents the most direct (and least costly) way of meeting regulatory demands. Some companies are downsizing their engine offerings by using direct injection and turbocharging to get fuel savings without a dramatic decrease in power. They are also using cylinder deactivation of larger engines to improve fuel economy. Companies are also moving to six- and seven-speed as well as continuously variable transmissions (CVT) to improve fuel economy.
- *Developing different types of hybrid powertrains*: Hybrid powertrains that combine electrical power with an internal-combustion engine for driving a vehicle now have a 10-year track record, but there is no sign that one form will dominate in the future. The different types of hybrid vehicles—including mild hybrids (e.g., General Motors, Honda), full hybrids (e.g., General Motors, Ford, Nissan, Toyota), and dual mode hybrids (e.g., Chrysler, General Motors)—are all in the marketplace. There are also some hydraulic and diesel hybrids being tested in some medium- and heavy-truck fleets. The upcoming hybrids include plug-in hybrids (e.g., Chevrolet Volt, Toyota Prius) that are expected to allow for longer pure electric performance. One can consider the plug-in hybrid as the next step in the evolution towards pure electric vehicles.
- *Developing advanced diesel powertrains:* Though diesel technology offers better fuel economy than gasoline engines, the additional initial cost of the diesel engine because of its size, complexity, and the aftertreatment technologies needed to manage emissions have delayed its introduction into some light vehicle fleets. Of course, nearly all heavy- and most medium-duty vehicles use diesel engines because of their durability and better fuel economy. There is continuing research by government and industry on Homogeneous Charge Combustion Ignition (HCCI), which makes gasoline engines behave like diesel engines in terms of improved fuel economy.
- *Developing hydrogen fuel cell powertrains:* Once considered the endgame for vehicle powertrains because they reduced dependence on foreign oil and produced no emissions from the vehicle, hydrogen fuel-cell powertrains (e.g., General Motors, Daimler, Honda,

Nissan, Toyota) ran into the twin challenges of cost of materials for the powertrain and the need for the development of a hydrogen infrastructure. Though the process of refueling for the consumer would be similar to current modes, the issue of the time it will take to develop a hydrogen infrastructure of fuel and stations has cooled expectations for this technology in the short term.

- *Developing pure electric vehicles:* The pure electric vehicle (e.g., BYD [Build Your Dreams], Mitsubishi, Nissan, Tesla, Toyota) offers a number of challenges and opportunities for governments, manufacturers, and suppliers. The opportunities include no emissions from the vehicles themselves, a fueling infrastructure that already exists, and a form of lithium-ion battery technology that already exists. The challenges include managing increased emissions and demand from electric power stations, developing batteries that provide enough range and performance for consumers, and providing enough public and private charging systems for vehicle owners. The governments, manufacturers, and some key suppliers around the world are all rushing to develop the battery technology to support this vehicle. One might consider these attempts similar to putting a man on the moon in the 1960s because of the enthusiasm and money put into this development.

Each country or region is using its own local views of its need for energy independence and control of emissions to develop its own strategy. In the following section, we will examine the strategies of four developed economies—the United States, Western Europe, Japan, and South Korea—and four developing economies—Brazil, Russia, India, and China—to see how their strategies may affect their countries' ability to turn over their fleets to ones with better overall fuel economy and fewer emissions.

Turning over the Fleet

The true endgame for the transition to vehicles with better fuel economy and fewer emissions is the length of time it will take to replace today's vehicles with vehicles using the new technologies. The sooner more fuel-efficient vehicles reach the consumer, the sooner the country will reap the benefits of less dependence on foreign oil and reduced GHG emissions. The current U.S. fleet is made up of 129 million passenger cars, 105 million light trucks, and about 7 million heavy-duty trucks. For this analysis, our focus will be on the 234 million light vehicles.

To measure the potential impact of these new technologies on sales over time is a very inexact science because of the unpredictability of external events (e.g. terrorist attacks, oil embargos, and recessions) and the uncertainty of technology breakthroughs or setbacks (e.g. battery and fuel-cell technology development). Nonetheless, the automakers worldwide must allocate production support for these technologies over the long term, and analysts predict what that production universe will supply.

Our analysis of fleet turnover for each country is based on the following steps:

1. *Establish a growth rate for each country:* We measure the growth of light-duty vehicle purchases over the last 32 years for developed economies (or the last 19 years for most developing economies) using Euromonitor International (2010) data for each country in the analysis. We establish an annual growth rate for light-duty vehicles. We then establish an overall average growth rate based on all the years in the analysis. The overall average growth rate is used to predict future vehicle growth for each country. For some countries, using the overall growth rate based on 32 or 19 years of data makes sense, but for some countries, especially those where growth has increased significantly since 2000, such as China, we used the growth rate for the years 2000 to 2009.

   The formula for determining the **annual growth rate** is:

   - Annual growth rate =
     (Number of vehicles-in-use in year N - number of vehicles-in-use in year (N-1)) / number of vehicles-in-use in year N

     Note: If the number of vehicles in year N-1 is greater than the number of vehicles in year N, then the growth rate is 0.

The formula for determining the **overall average growth rate** is:

- Overall average growth rate =
  Sum of all the annual growth rates / number of years in the analysis

2. *Establish a scrappage rate for each country:* Each country has an annual rate at which it replaces (scraps) the vehicles in its fleet. We measure the scrappage of light-duty vehicles over the last 32 years in developed economies (or the last 19 years for most developing economies) using Euromonitor International (2010) data for the countries in the analysis. We establish an annual scrappage rate for light-duty vehicles. We then establish an overall average scrappage rate based on all the years in the analysis. The overall average scrappage rate is used to predict future vehicle scrappage for each country. Again, for some countries, using the overall average scrappage rate based on 32 or 19 years of data makes sense, but for some countries, especially those where scrappage has increased significantly since 2000, such as China, we used the scrappage rate for the years 2000 to 2009.

   The formula for determining the **annual scrappage rate** is:

   - Annual scrappage rate =
     (Total number of new vehicles in year N - (number of vehicles-in-use in year N - number of vehicles-in-use in year (N-1))) / number of vehicles-in-use in year (N-1)

     Note: If the number of vehicles scrapped for year N-1 is greater than the number of vehicles scrapped for year N, then the scrappage rate is 0.

   The formula for determining the **overall average scrappage rate** is:

   - Overall average scrappage rate =
     Sum of all the annual scrappage rates / number of years in the analysis

3. *Establish a vehicle-in-use estimate for years 2010 to 2050 for each country:* By applying the overall average growth rate and the overall average scrappage rate to the previous year, we establish an estimate for vehicles-in-use for years 2010 to 2050. We chose 2050 as the final year for our analysis because it represents a significant time span to measure

fleet turnover—approximately 10 to 13 model changes (depending on whether one considers a model change of 3 or 4 years).

The formula for determining the estimate for **vehicles-in-use for each succeeding year** is:

- Vehicles-in-use for year N =
  Vehicles-in-use for year (N-1) + (Vehicles-in-use for year (N-1) * (overall growth rate +1))

4. *Establish a vehicle sales estimate for years 2010 to 2050 for each country*: By adding the estimates for growth and scrappage for each year, we establish an estimate for vehicle sales for the years 2010 to 2050. For some countries, using the overall average growth and scrappage rate based on 32 or 19 years of data makes sense, but for some countries, especially those where growth and/or scrappage has increased significantly since 2000, such as China, we used the growth and scrappage rates for the years 2000 to 2009.

   The formula for determining the estimate for **vehicle sales for each succeeding year** is:

   - Vehicle sales for year N =
     (Vehicles-in-use for year N - Vehicles-in-use for year (N-1)) + (Vehicles-in-use for year (N-1) * overall average scrappage rate)

5. *Establish three levels or models of penetration of alternative powertrains/fuels into each country's fleet for the years 2010 to 2050*: By using production forecasts provided by IHS Global Insight for powertrains/fuels for each country for 2010, 2015, and 2020, we establish what we call our *moderately aggressive model* for penetration of alternative powertrains/fuels into each country's new vehicle fleet from 2010 to 2020.

   For the years 2020 to 2050, we use our knowledge of past and current country policy, the current growth of alternative powertrains/fuels, and the recent sales growth to estimate the continued growth of alternative powertrains/fuels in new vehicles until alternative powertrains/fuels reach 100 percent of new-vehicle penetration. Using the moderately aggressive model as our baseline, we develop a *less aggressive model* and a *very aggressive model* of alternative powertrains/fuels into the new vehicle fleet. In the less aggressive model, it takes longer than in the moderately aggressive model for 100 percent alternative powertrains/fuels penetration in the new vehicle fleet, while in the very aggressive model it takes less time to reach 100 percent alternative powertrains/fuels penetration in the new vehicle fleet. For the less aggressive model, we chose 2050 as the year most of the countries in our analysis reach 100 percent penetration of alternative powertrains/fuels, based on our country analysis of automotive powertrains/fuels policies, current and future trends of alternative powertrains/fuels, and predicted overall sales growth.

Our definition for alternative powertrains/fuels eliminates pure gasoline and diesel powertrains/fuels, but it does include the hybridization of these fuels. Our list of possible alternative powertrains/fuels includes:

- Compressed natural gas (CNG)
- CNG/diesel hybrid
- Diesel/electric hybrid
- Gasoline/electric hybrid
- Gasoline/CNG hybrid
- Gasoline/liquefied petroleum gas (LPG) hybrid
- Pure electric
- Ethanol (E85)
- Ethanol (E85)/electric hybrid
- Hydrogen
- Fuel cell

For each country we show a graph that contains a plot of each of the three models from 2010 to 2050, the year in which alternative powertrains/fuels reach 100 percent penetration in the new vehicle fleet, and the path of overall vehicle fleet growth from 2010 to 2050. In the text, we also report alternative powertrains/fuel estimates for each model for 2010, 2015, and 2020; the year in which alternative powertrains/fuels reach 100 percent penetration in the new vehicle fleet; and the year each country's fleet completely turns over to alternative powertrains/fuels.

6. *Establish vehicles-in-use, scrappage, and sales estimates for vehicles in the fleet using the old technology/fuels and vehicles using the alternative powertrains/fuels:* As alternative powertrains/fuels enter the fleet, they age and eventually need to be scrapped or replaced. We establish estimates for the old and alternative powertrains/fuels as their distribution within the overall fleet changes annually.

   The formula for determining the estimate for **sales of alternative powertrains/fuels by year** is:

   - Alternative powertrains/fuels vehicle sales =
     Vehicle sales for year N * percentage of sales of alternative powertrains/fuels assumed for year N for each model

     (less aggressive, moderately aggressive, and very aggressive)

   The formula for determining the estimate for **sales of old technology/fuels by year** is:

   - Old technology vehicle sales =
     Vehicle sales estimate for year N - alternative powertrains/fuels vehicle sales estimate

   The formula for determining the estimate for **vehicles-in-use using alternative powertrains/fuels by year** is:

   - Vehicles-in-use using alternative powertrains/fuels =
     Vehicles-in-use for year N * percentage of alternative powertrains/fuels for year N

     (Starting percentage for 2010 comes from IHS Global Insight.)

   The formula for determining the estimate for **vehicles-in-use using old technology/fuels by year** is:

   - Vehicles-in-use using old technology =
     Vehicles-in-use for year N - vehicles-in-use using alternative powertrains/fuels for year N

     (Starting percentage for 2010 comes from IHS Global Insight.)

The formula for determining the estimate for **scrappage of vehicles using alternative powertrains/fuels by year** is:

- Scrappage of vehicles using alternative powertrains/fuels = Vehicles-in-use for year N using alternative powertrains/fuels * overall average scrappage rate

The formula for determining the estimate for **scrappage of vehicles using old technology by year** is:

- Scrappage of vehicles using old technology = Vehicles-in-use for year N using old technology * overall average scrappage rate

The formula for determining the estimate for **scrappage of all vehicles by year** is:

- Scrappage of all vehicles = Scrappage of vehicles using old technology + scrappage of vehicles using alternative powertrains

7. *Establish the percentage of vehicles-in-use using alternative powertrains/fuels for 2010 to 2050:* We establish a continuing estimate for the penetration of alternative powertrains/fuels in the fleet from 2010 to 2050.

The formula for determining the estimate for **vehicles-in-use using alternative powertrains/fuels by year** is:

- Vehicles-in-use using alternative powertrains = Number of sales of vehicles-in-use using alternative powertrains for year N / total number of vehicles-in-use for year N

The United States Market: Turning Over a Very Large Fleet

The U.S. market, prior to 2009, was the largest automotive market in the world. It is still the country with the largest number of vehicles per capita (1.2 persons per vehicle; 2.2 persons per light vehicle), and the most vehicles in the fleet (nearly 250 million). When transitioning a country's fleet of vehicles to one that allows the country to be less dependent on foreign oil through more fuel-efficient vehicles while at the same time reducing GHG emissions, the United States, relative to other countries, faces the biggest challenge. It must not only physically turn over its large fleet of vehicles but also psychologically migrate customer expectations and demand towards more fuel-efficient vehicles. All other developed economies have already migrated customer expectations toward vehicles that provide better fuel economy through higher fuel prices driven by increases in fuel taxes. But the United States has only begun this process, and it is trying to do it without increasing the price of fuel.

Regulatory Efforts

One can best describe the U.S. government's efforts to support improved fuel economy over the past 30 years as inconsistent. The twin oil shocks of the 1970s forced the government to enact policies (the Corporate Average Fuel Economy (CAFE) regulations) that demanded improved fuel economy by auto manufacturers. But once oil prices and supply stabilized, improvements in CAFE regulations stagnated until President Bush's 2008 State of the Union Address.

The government is trying to do this through regulation and by encouraging the development of new technologies that support the twin goals of increased fuel economy (thus reducing dependence on foreign oil) and reduced GHG emissions. The CAFE standards and GHG emissions regulations are for the first time being merged to provide one goal for automakers. The government now requires the National Highway Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) to jointly manage fuel economy, while EPA continues to regulate emissions. These are early days in the collaboration of these two agencies, so it is unclear how successful they will be in their collaboration. Each automaker selling vehicles in the United States has fleet goals (their corporate average fleet fuel economy) they must meet by 2016 or face fines. There are more rigorous goals in discussion for 2020 that will depend on the technological advancements available to the manufacturers.

One would be remiss not to mention the effect of the state of California on U.S. environmental policy. Since the 1970s, California has been in the vanguard of pushing the federal government and automakers to improve vehicle emissions. It even received a waiver from the Environmental Protection Agency and the U.S. Supreme Court allowing it to set its own emissions standards. The waiver effectively gave California power to regulate emissions policy for all of the United States. California represents the state with the largest annual new-vehicle sales, representing about 12 percent of all U.S. sales, and automakers could not ignore California's regulations. When a group of 13 northeastern states followed California's lead in adopting its standards, the industry effectively became governed by California's regulations. This meant regularly lobbying California's Air Resources Board (CARB) to provide information about the current state of emissions technology and the cost of including these technologies on new vehicles. When CARB was given the authority to regulate its own GHG emissions recently, it also indirectly became involved in fuel-economy standards because fuel economy is strongly related to controlling GHG emissions. All of this led to the NHTSA and EPA regulatory collaboration, and their adopting California's regulations for 2016.

Innovation Efforts

A dramatic rise in gas prices in the spring and summer of 2008, the beginning of the deepest recession since the 1930s in September 2008, the collapse of the auto market in 2009, and the bailout and bankruptcies of General Motors and Chrysler have all combined to not only continue the momentum to increase fuel economy and reduce emissions, but to actually increase the urgency, funding, and regulations to meet these goals. In early 2010, the government stated that manufacturers would have to increase their fleet fuel economy by 40 percent by 2016 instead of 2020.

The government is currently very aggressive in its support for the development of new technologies. It is supporting development in its national labs, universities, and in combination with the private sector through its support for new powertrain technology development as well as support for changing over manufacturing plants from old to new technology.

Because each manufacturer will have a different goal for 2016 based on its fleet average in 2010, each company is taking a different path to meeting its goal. But it is clear that manufacturers and suppliers are also looking farther ahead to 2020 and beyond. Companies always considered fuel economy when designing new vehicles, but the equation they used to determine what they would put into a vehicle relative to the price of the vehicle has changed. Companies are bringing more small vehicles into their fleets, considering new materials for decreasing the weight of vehicles, and researching different powertrains to find the appropriate technologies that will allow them to meet current and future regulations. Some of the powertrain technologies are improvements of current powertrains while others require a paradigm shift of consumer behavior and U.S. energy infrastructure. What is unclear is which technology will dominate in the future.

Our own research on this topic in 2006 and 2007 shows the effects of the new CAFE policy discussions that took place late in 2006. As shown in Figure 10, though experts in our survey predicted significant increases in hybrid and diesel penetration in 2020 (Belzowski, 2008), the change in the penetration of gasoline engines and diesel engines shows the uncertainty at that time about the actual penetration of each technology in 2020.

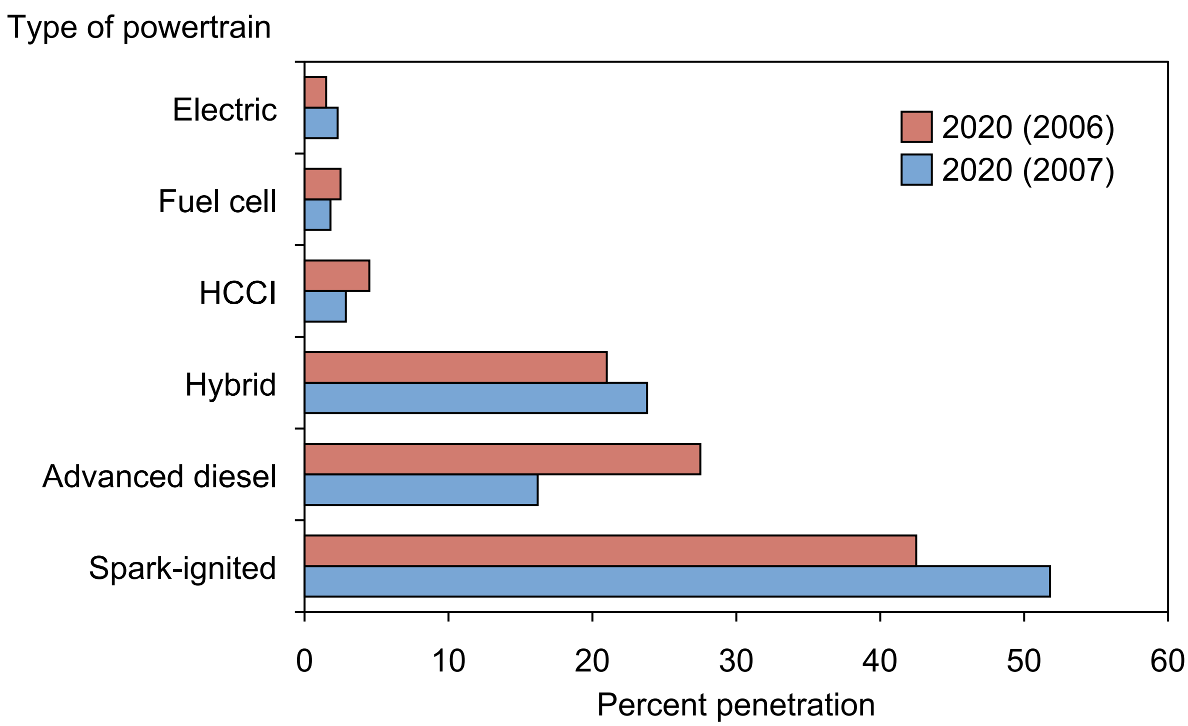

Figure 10. Powertrain penetration in the United States in 2020 (Belzowski, 2008).

Our colleagues at IHS Global Insight (IHS Global Insight, 2010) expect the following powertrains/fuels to make up the bulk of the alternative powertrains/fuels in the United States over the next 10 years: CNG, CNG/electric hybrid, diesel/electric hybrid, pure electric, ethanol (E85), ethanol/electric hybrid, gas/electric hybrid. They expect ethanol (E85) to make great strides over the next 10 years, supporting nearly as many powertrains as gasoline.

Fleet Turnover Analysis

With a fleet of nearly 250 million vehicles, the United States is challenged to turn this fleet over. As shown in Table 1 and Figure 11, in the less aggressive turnover model, 77 percent of the fleet is turned over by 2050; in the moderately aggressive model, 84 percent of the fleet is turned over; and in the very aggressive model, 93 percent of the fleet is turned over by 2050. As noted above, these assumptions are based on the significant growth of ethanol (E85). If the process for creating this biofuel does not develop beyond its current corn-based form, it is unlikely that the government will sacrifice the food supply based on corn for fuel.

Table 1
U.S. fleet turnover statistics.

U.S. fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	21%	21%	21%
Alternative powertrains/fuel: 2015	33%	47%	55%
Alternative powertrains/fuel: 2020	43%	49%	80%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2040	2024
Fleet turned over by 2050	77%	84%	93%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

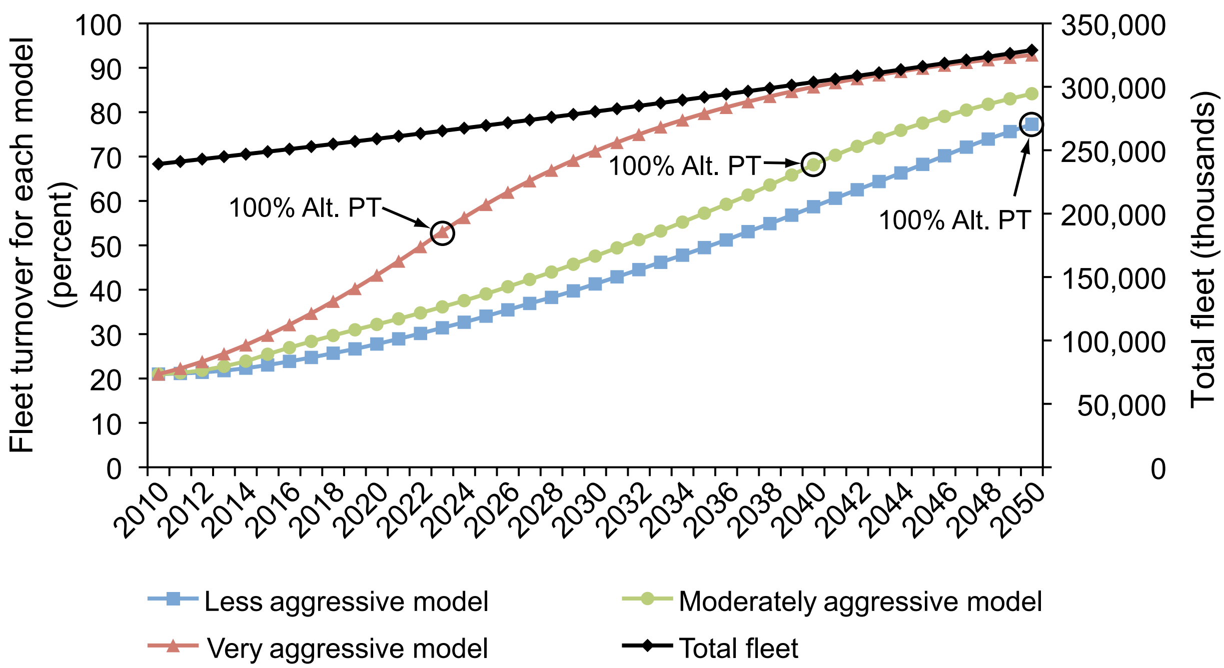

Figure 11. Turnover of the U.S. fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

The US still has a card to play that most other countries do not have: increasing fuel taxes. Many other countries already have very high fuel prices because of the taxes added into the price of fuel. These higher prices forced buyers into more fuel-efficient vehicles many years ago, and now governments cannot raise the taxes without causing significant hardship to the populace of their countries. Though increasing fuel taxes in the U.S. is considered political suicide, if events occur that demand that the country move to more fuel-efficient vehicles in a short period of time, the government can raise fuel taxes without causing the hardship that other countries would face.

Western Europe: The Diesel Dilemma

Western Europe, with over 240 million vehicles in its fleet, has a similar dilemma to that of the U.S. in its need to turn over a large fleet, but the Western European market is very different from the U.S. market. Western Europeans after the Second World War used high gasoline taxes to control the use of a scarce resource. Though Western Europe is made up of many different countries, all of them used this same strategy to manage their fuel supply. This method of managing fuel economy continues today with fuel prices nearly three times the price of fuel in the U.S. Because Western Europe has managed its fuel supply in this way for such a long time, its population has adapted to higher prices and manufacturers have developed vehicles that are very fuel efficient.

Regulatory Efforts

One major difference between Western Europe and the rest of the world is its support for diesel fuel for passenger cars. Because of high fuel taxes/prices, the fuel economy offered by diesel fuel was always an attractive option for Western European buyers, but the emissions from these engines were noxious to people, especially in larger cities. With the development of more efficient diesel engines that met stricter emissions requirements in the 1990s, governments supported diesel fuel by subsidizing the cost of diesel fuel by as much as 30 percent, driving the sale of diesel-fueled vehicles from about 20 percent of the market in the 1990s to over 50 percent of the market in 2008.

Having moved its new vehicle fleet to the most fuel-efficient fuel currently available, governments next focused on CO2 emissions in order to meet GHG standards (and also because it would be extremely expensive to improve the fuel economy of current vehicles without more expensive new technologies). Western Europe developed very strict future goals for CO2 emissions that have created a stir within the auto manufacturer community, especially from the luxury vehicle manufacturers. Manufacturers do not have the technology currently available to meet these requirements without increasing technology costs dramatically or sacrificing performance or both. The conversation between regulators and the vehicle manufacturers about the viability of meeting these strict regulations continues.

Innovation Efforts

Though the subsidies of diesel fuel by Western European governments increased the fuel economy of its fleet, it put European manufacturers at a disadvantage in other markets, especially in the U.S. Though diesel fuel does provide better fuel economy and its emissions are dramatically reduced, U.S. regulators measure emissions differently from European regulators. The particulate emissions from diesel fuel make diesel engines illegal within the U.S. unless they also use aftertreatment methods to capture them, which makes the diesel engine more expensive than its gasoline counterpart.

Western European manufacturers and suppliers are working to overcome the cost disadvantage of diesel fuel in the U.S., but they are also developing diesel hybrid engines, pure electric, and fuel-cell vehicles for the European and U.S. markets. All the major manufacturers are putting significant research and development into these technologies with the goal of not only improving CO2 emissions but also improving fuel economy in the same process.

For Western Europe, IHS Global Insight (IHS Global Insight, 2010) expects the following technologies to play a role in the Western European market: diesel/CNG hybrid, diesel/electric hybrid, pure electric, ethanol (E85), ethanol/electric hybrid, fuel cell, gas/CNG hybrid, gas/CNG/electric hybrid, gas/LPG, gas/LPG/electric hybrid, gas/electric hybrid. Because countries are working independently to develop these new powertrains, there is a proliferation of combinations of powertrains/fuels, though IHS Global Insight expects diesel/electric and gas/electric hybrids to be the dominant alternative powertrains in production by 2020.

Fleet Turnover Analysis

Like the United States, Western Europe's large fleet makes it difficult to turn over quickly, especially if different countries are focusing on different powertrains/fuels. As is the case in the United States, it is very difficult to turn over the fleet, because even though the alternative powertrains/fuels will become 100 percent of new vehicle sales, they also will become part of the scrappage cycle. As our analysis shows in Table 2 and Figure 12, 69 percent of the fleet would be turned over by 2050 in the less aggressive model, 83 percent of the fleet would be turned over in the moderately aggressive model, and 90 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 2
Western European fleet turnover statistics.

Western European fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	17%	17%	17%
Alternative powertrains/fuel: 2015	29%	63%	75%
Alternative powertrains/fuel: 2020	39%	78%	97%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2027	2022
Fleet turned over by 2050	69%	83%	90%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

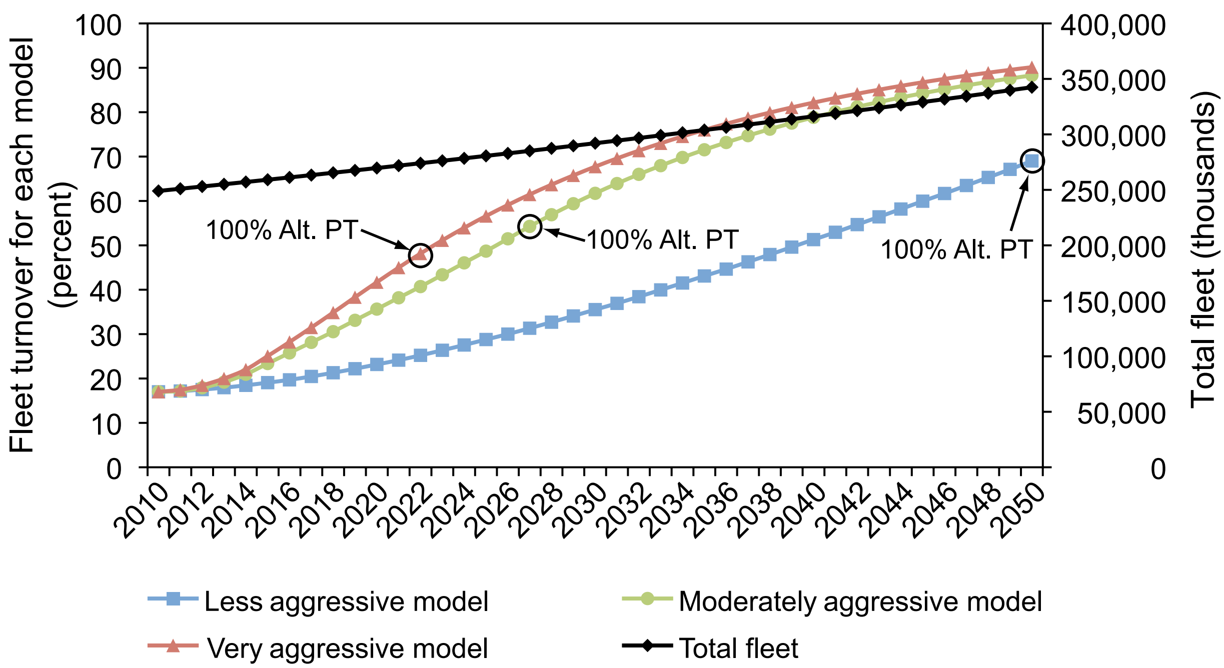

Figure 12. Turnover of the Western European fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

Japan: It's a Hybrid/Electric World

With a fleet of nearly 57 million vehicles, Japan has been a leader in developing alternative powertrain technology, focusing on the development of hybrid technology and minicars, rather than diesel technology. Because of its lack of domestic oil, Japan pushed for technological solutions to its dilemma, and Honda and Toyota developed the first production gas/electric hybrid vehicles. The government also promoted standards that led to the proliferation of minicars, vehicles with engines with a displacement of less than 660 cubic centimeters. Another possible reason for the success of minicars may be Japan's inspection system, which tends to force vehicle owners to purchase a new vehicle rather than pay for expensive repairs that are needed to pass a biannual inspection. Though the inspection system keeps all vehicles in top condition to provide the best fuel economy and the least emissions, vehicle owners who think they are continually buying a new vehicle to avoid the cost of inspections may opt to purchase the least expensive vehicle on the market, like a minicar, to lessen the effect of constantly buying a new vehicle.

Regulatory Efforts

Like the U.S. during the oil shocks of the 1970s, Japan established its energy conservation law in 1979, and introduced its Top Runner approach to fuel economy and emissions in 1998. In this approach, the government measures what is the best current technology for fuel economy or emissions and sets the target for the rest of the fleet based on this "best in class" standard. The government reasons that the standard is high but reachable because some vehicles in the current fleet have already reached the target values. Similar to the new CAFE regulations in the U.S. that take into account the "footprint" of the vehicle, the targets for Japanese vehicles are based on the weight category of a vehicle. The other variable in target values is the size of the engine, and there can be significant differences in the goals for vehicles with engines less than and greater than 600 cubic centimeters. Finally, like Western Europe, Japan uses high fuel taxes to stimulate purchases of vehicles with better fuel economy, but Japan does not support the use of diesel fuel as the Europeans do.

For over three years, both the local and national government have provided tax incentives for alternative powertrain technologies as well as for conventional internal-combustion engines that meet fuel economy standards. Because the incentive program has been available for a long period of time, some government officials are uncertain what type of vehicle buyers will purchase once the incentives are decreased or withdrawn. Finally, Japan has developed what it calls an integrated approach to fuel economy and emissions that focuses on vehicle performance (supporting vehicles with improved fuel efficiency), usage improvement (encouraging other modes of transport [modal shift] and more efficient truck transportation), and infrastructure improvement (improving traffic flow and reducing congestion using ITS). These changes are expected to take place across passenger vehicles, freight vehicles, and other modes of transport.

Innovation Efforts

Japan has succeeded in stimulating its manufacturers and suppliers to develop many of the new technologies that support its vision for reducing fuel consumption and CO2 emissions, but much work needs to be done. Nearly all manufacturers have teamed up with the major global electronics firms to develop the next generation of batteries needed for hybrid and pure electric vehicles. Though there are significant technological hurdles to overcome for pure electric and fuel-cell technologies, all the major manufacturers have significant development programs that support the development of these alternative powertrains. Because of this national commitment to these technologies, many consider Japan a leader in these new technologies. Though both Honda and Toyota show continued improvement in their fuel-cell vehicles, they do not seem to have overcome the battery challenges that are holding back the rest of the world (i.e., batteries that provide the same range as gasoline powered vehicles in all climates). Nissan is leading the global manufacturers in pure electric vehicles with the introduction of the LEAF in 2010. The LEAF is predicted to have a driving range of 100 miles per charge, which will be the highest range for an electric vehicle produced today.

For Japan, IHS Global Insight (IHS Global Insight, 2010) predicts the following alternative powertrains/fuels will play a role in the period 2010 to 2020: CNG, CNG/electric hybrid, diesel/electric hybrid, pure electric, fuel cell, gas/CNG, gas/hydrogen hybrid, gas/hydrogen/electric hybrid, gas/LPG, LPG, gas/LPG/electric hybrid, and gas/electric hybrid. They expect the gas/electric hybrid technology to be the dominant alternative powertrain in production in 2020.

Fleet Turnover Analysis

Japan's smaller fleet and high new-vehicle sales relative to the size of its fleet make it more likely than other developed economies to turn over its fleet. Our analysis shows in Table 3 and Figure 13, that 72 percent of the fleet would be turned over by 2050 in the less aggressive model, 88 percent of the fleet would be turned over in the moderately aggressive model, and 93 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 3
Japanese fleet turnover statistics.

Japanese fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	15%	15%	15%
Alternative powertrains/fuel: 2015	25%	37%	45%
Alternative powertrains/fuel: 2020	31%	40%	70%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2034	2024
Fleet turned over by 2050	72%	88%	93%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

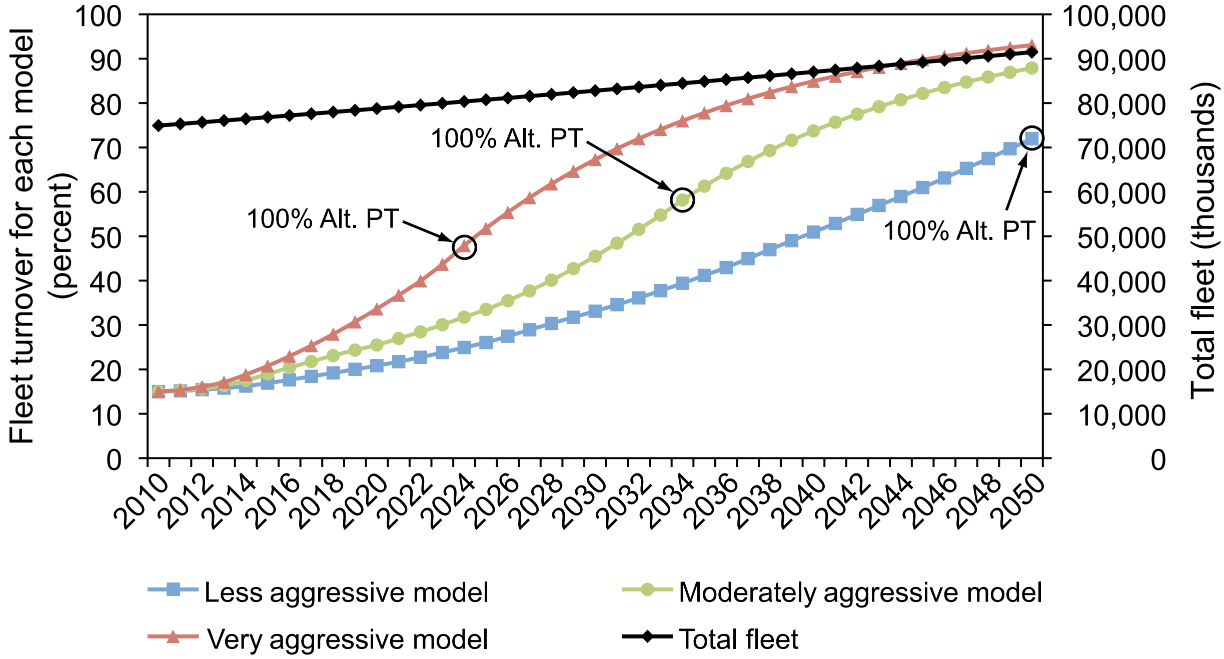

Figure 13. Turnover of the Japanese fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

South Korea: The Fast Follower

South Korea with its small fleet of about 16 million vehicles has always been a country that followed the lead of other countries in the global auto industry. The two national brands, Hyundai and Kia, now produce very successful vehicles after initial quality and reliability problems. They have also developed a significant global presence in China and India, as well as in the United States, Europe, and South America. But neither company has any vehicle offerings using alternative powertrains/fuel. Hybrid vehicles are nearing production, but it will be some time before they reach any large-scale production and sales.

Regulatory Efforts

The South Korean government, as part of its stimulus package to combat the global recession, instituted a "Green New Deal" that is designed to spend nearly $35 billion on the development of Green Technologies (UNEP, 2009). This investment means that South Korea is spending more of its stimulus package (79 percent) than any other country in the world on green technologies (UNEP, 2009). Low-carbon vehicles are part of this development, but it is unclear how this will play out in the marketplace. As part of its focus on green technology, the South Korean government announced in 2009 that it would set fuel-economy standards for 2012 for locally produced vehicles that would exceed U.S. and Japanese standards (Green Car Congress, 2009). The question that arises from these efforts is what kinds of vehicles are in development to support these regulations in South Korea?

Innovation Efforts

One area where South Korea has excelled is in the area of battery technology development. For example, its electronics firm, LG Chem, was chosen by General Motors to provide the battery packs for its Volt plug-in hybrid vehicle. Our research on the South Korean auto industry in 2006-2007 showed that South Korean powertrain experts expected growth in alternative powertrains/fuels, as seen in Figures 14 and 15 (Belzowski and Lee, 2008).

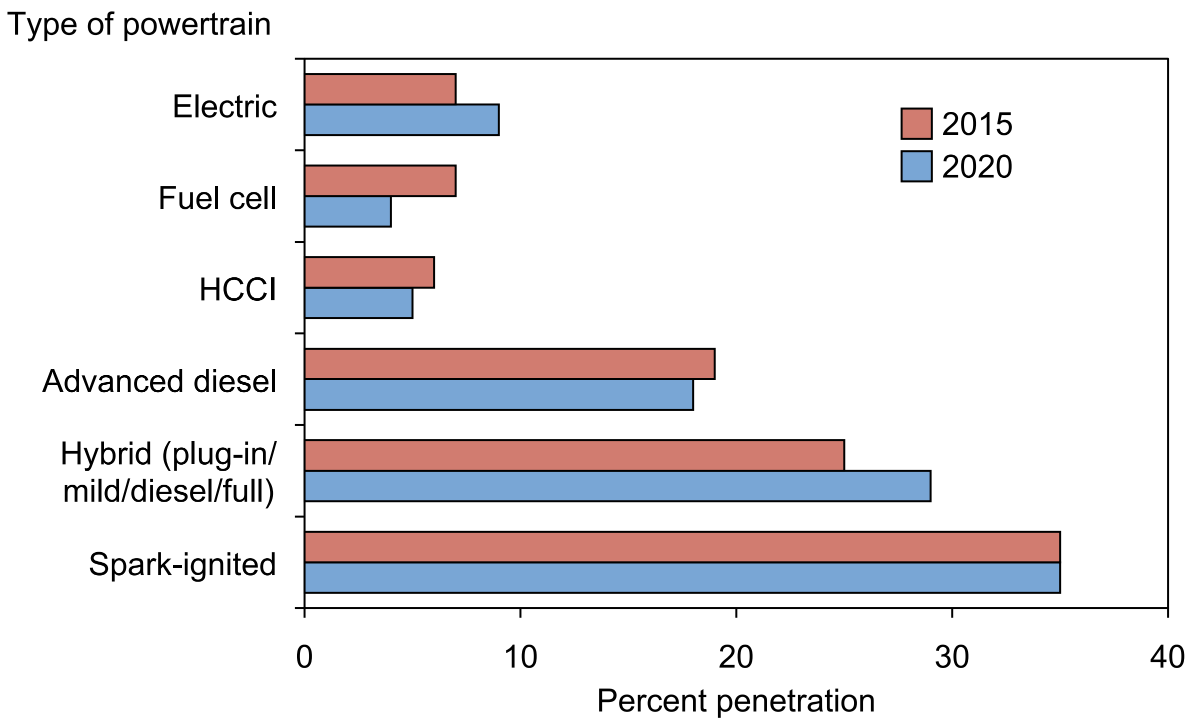

Figure 14. Powertrains for South Korean passenger cars (Belzowski, 2008).

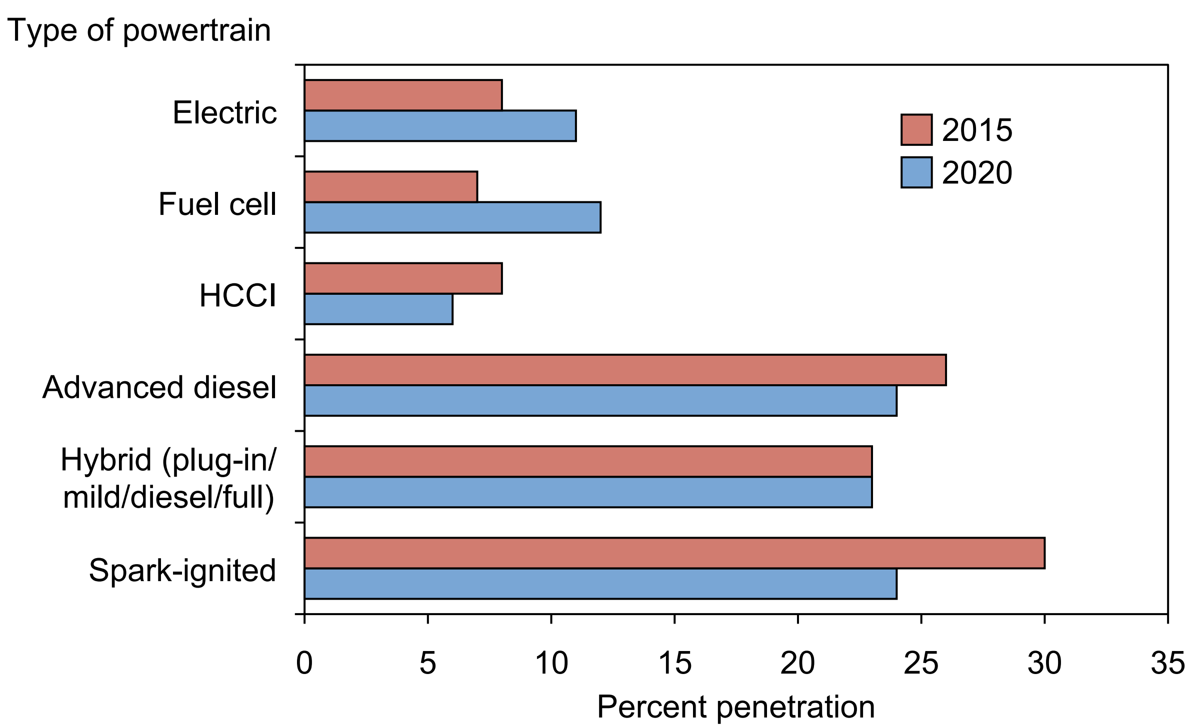

Figure 15. Powertrains for South Korean light trucks (Belzowski, 2008).

IHS Global Insight (IHS Global Insight, 2010) is not as optimistic about alternative powertrains/fuels in the South Korean market. By 2020, they expect the following powertrains/fuels to represent the alternative powertrains/fuels: CNG, diesel/electric hybrid, pure electric, fuel cell, gas/electric hybrid, gas/LPG, LPG, and LPG/electric hybrid, with gas/LPG as the main alternative fuel. But they do not see significant production of these powertrains/fuels relative to gasoline or diesel fuels.

Fleet Turnover Analysis

Because South Korea is a fast follower in the global automotive industry, our model for turning over their fleet predicts low percentages of sales of vehicles with alternative powertrains/fuels in the short term, but significant increases in the long term. Because it is a fast follower, and even though South Korea has a small fleet of vehicles, its low predicted production of alternative powertrains/fueled vehicles in the short-term means it will take longer to turn over its fleet relative to other developed economies. Our analysis shows in Table 4 and Figure 16 that only 60 percent of the fleet would be turned over by 2050 in the less aggressive model, 80 percent of the fleet would be turned over in the moderately aggressive model, and 87 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 4
South Korean fleet turnover statistics.

South Korean fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	9%	9%	9%
Alternative powertrains/fuel: 2015	10%	13%	30%
Alternative powertrains/fuel: 2020	12%	16%	42%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2040	2035
Fleet turned over by 2050	60%	80%	87%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

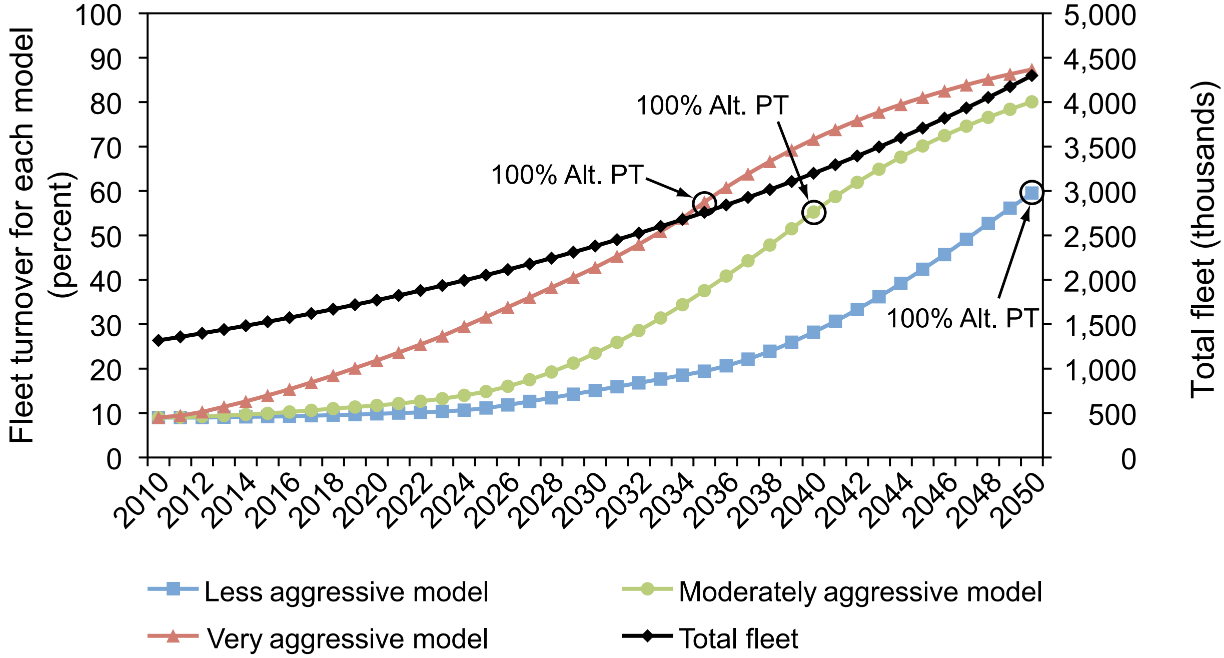

Figure 16. Turnover of the South Korean fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

Brazil: The World of Ethanol

Brazil has become the model for how to become independent of foreign oil. Because of its large land mass, a climate conducive to multiple yields of sugarcane from various parts of the country, and over 30 years of researching, managing, and producing ethanol from sugar cane, Brazil has made the transition to energy security. Brazil uses a variety of blends of ethanol as well as pure ethanol to support its 25 million-vehicle fleet. Though there are still gasoline and diesel vehicles sold in Brazil, ethanol-based vehicles represent over 80 percent of all vehicles sold. Also, though there are no domestic manufacturers in Brazil, all the foreign manufacturers design vehicles to support the different blends of ethanol. The designs include engines that are optimized to generate the best combustion for the blend of ethanol being used.

Regulatory Efforts

The government has developed a variety of blends of ethanol that can be used in any of the vehicles developed and sold in Brazil. Many vehicles have switches that adjust the settings of the engine to adapt to particular blends of ethanol fuel. One drawback of ethanol is that it does not burn as efficiently as gasoline and diesel, thus providing fewer kilometers per liter than gasoline and diesel fuel. The government has developed a decision rule for drivers, which allows them to decide which type of fuel to purchase based on the price of gasoline, diesel, and the different blends of ethanol.

Brazil’s 2008 emissions regulations that go into effect in 2012 are based on Euro V standards, so Brazil’s current Euro IV standards are less stringent than current standards in Europe. Over the last 30 years, the government and outside researchers have conducted extensive research on the effects of ethanol from sugarcane as it relates to total lifecycle costs, GHG emissions, energy balance, agricultural technology, the production process, land use change, social/labor implications, and the effects on food prices. Though there are some conflicting views on some of these issues, the government has succeeded in presenting enough evidence, to the country and the world, to support its position on the use of sugarcane to create ethanol as a long-term strategy to reduce Brazil’s dependence on foreign oil.

Innovation Efforts

Over the last 30 years, the government-supported research on various strains of sugarcane that yields the best ethanol has created an internal sugarcane economy that supports the Brazilian automotive industry. The success of the sugarcane economy has meant that the government does not provide internal subsidies for the sale of ethanol and can export the fuel throughout the world. Over time, manufacturers have adapted and designed vehicles that support Brazil's move to an ethanol economy.

IHS Global Insight (IHS Global Insight, 2010) also sees the future of Brazil tied to ethanol. By 2020, they expect only the following powertrains/fuels to represent the alternative powertrains/fuels: ethanol (E85), ethanol/CNG, with ethanol as the main alternative fuel.

Fleet Turnover Analysis

Because Brazil already has converted over 80 percent of its fleet to some form of ethanol blend, it has the opportunity to move more quickly to a point where 100 percent of new vehicles sold use alternative powertrains/fuel. This fact, combined with a relatively small fleet of vehicles, implies that Brazil can turn over nearly 98 percent of its fleet to alternative powertrains/fuel by 2050. As shown in Table 5 and Figure 17, 95 percent of the fleet would be turned over by 2050 in the less aggressive model, 98 percent of the fleet would be turned over in the moderately aggressive model, and 99 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 5
Brazilian fleet turnover statistics.

Brazilian fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	88%	88%	88%
Alternative powertrains/fuel: 2015	90%	90%	90%
Alternative powertrains/fuel: 2020	90%	90%	90%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2041	2029	2023
Fleet turned over by 2050	95%	98%	99%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

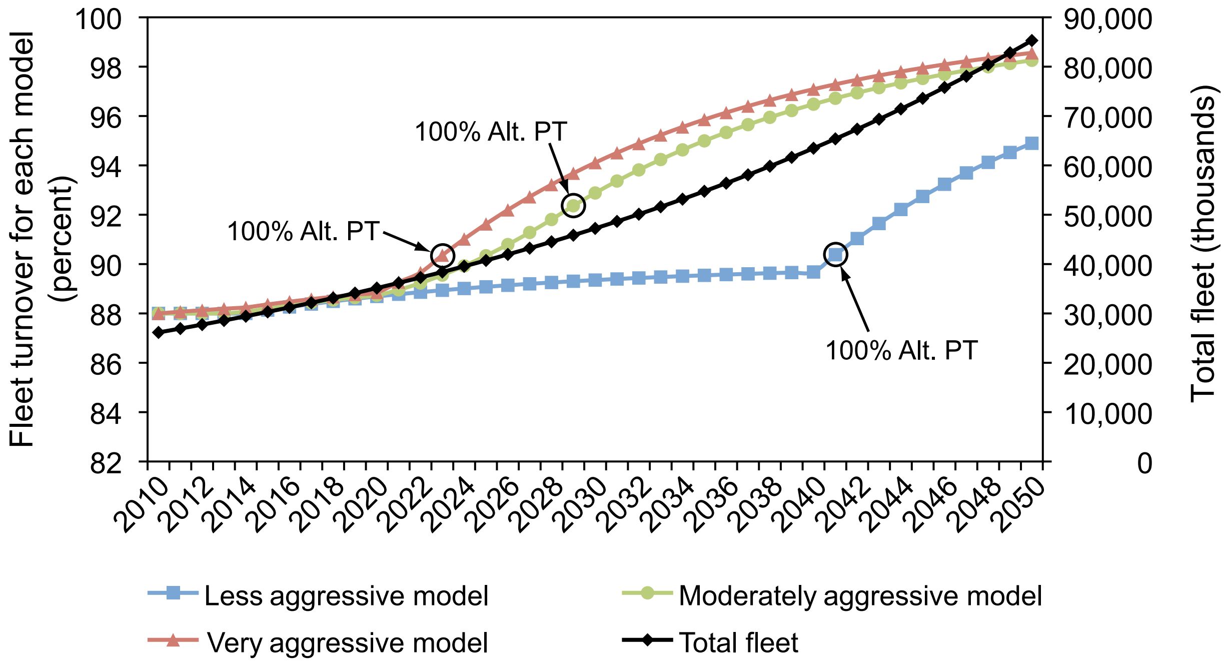

Figure 17. Turnover of the Brazilian fleet (IHS Global Insight, 2010; Euromonitor International, 2010). (Because all the models begin at 88 percent penetration of alternative powertrains/fuels, the less aggressive model takes a number of years before beginning to show increased penetration.)

Russia: What’s Wrong with Oil Dependence?

With its fleet of nearly 30 million vehicles, Russia has a lot of work to do in order to turn over its fleet to vehicles that are more fuel-efficient and with fewer emissions. But the government does not seem to be in much of a hurry to move in this direction, most likely because of its large petroleum reserves, which make Russia one of the few major countries that can fuel its own automotive future with petroleum.

Prior to the global recession, Russia was considered one of the up-and-coming automotive economies. Its sales were growing significantly, and it looked like it might overtake Germany as the largest market in Europe. But the recession has dampened those goals. The current Russian government has recently developed its stimulus plan for the auto industry, which places high tariffs on imports of vehicles in order to support its domestic manufacturer, AutoVAZ, and which invests US$20 billion (to be matched by US$20 billion from foreign manufacturers) for technology development, retraining of employees, direct subsidies, and a “Cash for Clunkers” program (Niedermeyer, 2010). What is noticeable is that Russia is improving its infrastructure and sees no reason to promote alternative powertrains/fuels because of its supply of petroleum.

Regulatory Efforts

Though its large supply of petroleum, owned primarily by the government, seems to dictate that the government will act in its best interests and delay the introduction of alternative powertrains/fuels, the government is committed to reducing emissions by adopting Euro IV emissions standards for 2010. It also seems that the government is interested in having foreign manufacturers support the cost of developing any new technologies through its insistence that they provide half of the funding for “technology development.” It may be that foreign manufacturers will be able to “pay” their portion of the stimulus by providing their new technology to the government, thereby providing Russia’s research and development for the new technologies.

Innovation Efforts

Though the government does not seem in any hurry to develop alternative powertrains/fuels for its vehicles, it is allowing one of Russia's billionaires, Mikhail Prokhorov, to develop hybrid vehicles to be built and sold in Russia. Mr. Prokhorov states that the vehicles will cost US$10,000 and will run on regular gasoline or CNG (RIA Novosti, 2010).

The other major initiative is a Global Environment Facility grant recently approved and administered through the United Nations Development Programme entitled "Reducing GHG Emissions from Road Transport in Russia's Medium-sized Cities" (Global Environment Facility, 2010). This grant provides about US$40 million to two medium-sized Russian cities to "establish a national policy and regulatory framework to support market transformation towards more efficient and less carbon intensive transport modes. By tightening fuel efficiency standards, along with introducing car labeling and public awareness campaigns, the project will speed up efficient renewal of the country's car fleet and drive the desired changes in consumer behavior. The project will also capitalize on the opportunity to demonstrate sustainable and low-carbon transport solutions at a big international event – 2013 World University Games in Kazan, Tatarstan Republic (XXVII Summer Universiade)."

IHS Global Insight (IHS Global Insight, 2010) sees an automotive future for Russia dominated by gasoline, diesel, and CNG. But by 2020, they expect the following powertrains/fuels to represent the alternative powertrains/fuels: diesel/CNG, diesel/electric hybrid, ethanol (E85), gas/CNG, gas/CNG/electric hybrid, and gas/electric hybrid, with gas/electric hybrid as the main alternative powertrain/fuel.

Fleet Turnover Analysis

The combination of Russia being less aggressive in introducing or supporting new alternative powertrains/fuels with a somewhat larger fleet of vehicles means that it will take longer for Russia to turn over its fleet. Our analysis shows in Table 6 and Figure 18 that only 64 percent of the fleet would be turned over by 2050 in the less aggressive model, 75 percent of the fleet would be turned over in the moderately aggressive model, and 83 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 6
Russian fleet turnover statistics.

Russian fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	0.5%	0.5%	0.5%
Alternative powertrains/fuel: 2015	5%	7%	10%
Alternative powertrains/fuel: 2020	10%	14%	25%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2044	2040
Fleet turned over by 2050	64%	75%	83%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

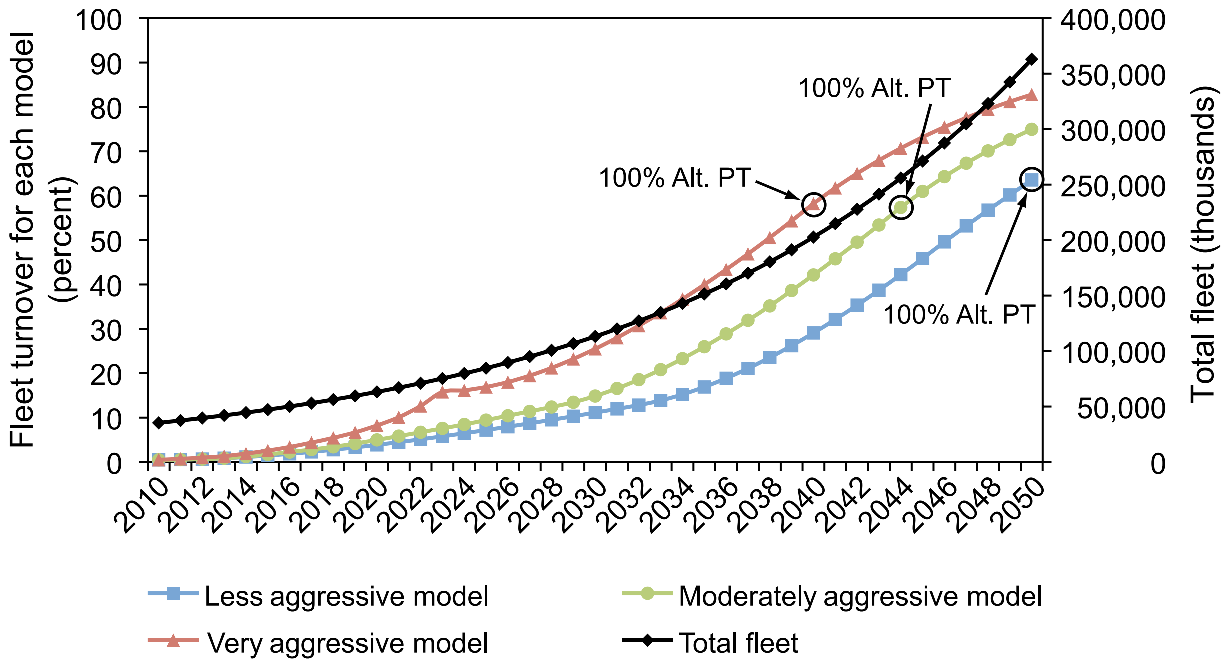

Figure 18. Turnover of the Russian fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

India: Moving from two wheelers to four wheelers

As an automotive market, India represents tremendous untapped potential. Compared to the explosive growth in China, India is in the very early stages of automotive market development. Though India has nearly as many people as China, its automotive market is growing at a much slower pace. This also is represented in the types of vehicles sold in India. India is the second largest market in the world for motorcycles (2 wheelers in Indian terms). Its population is just beginning the process of moving from 2 wheelers to 4 wheelers. The US$2,500 Tata Nano, which was developed with the express purpose of moving people from 2 wheelers to 4 wheelers, is an example of the evolution of their automotive market. With about 24 million vehicles in its fleet, India ranks as one of the larger fleets in the world, but not on a per capita basis (about 75 persons per vehicle) when compared to other large developing economies (about 25 persons per vehicle in China).

Regulatory Efforts

India, like many other countries, does not have large petroleum reserves, so as its automotive economy grows it must promote the development of more fuel-efficient vehicles (though the country already sells mostly small, fuel-efficient vehicles). As a developing economy, it is not under the same pressure to reduce GHG emissions as developed economies, though eventually it must address this issue. From an emissions perspective, the government has committed to Euro IV standards for 2010, so there is continued movement towards improved emissions. The government is still struggling to develop national highways as well as good secondary road systems that support a vibrant automotive economy. In the future, India may be able to tap into its expertise in nuclear power to support the development of pure electric or plug-in hybrid/electric vehicles, but its infrastructure and low household incomes remain significant barriers to this goal. In some ways, the path to alternative powertrains/fuels is similar to Russia's but for completely different reasons. India's growth in alternative powertrains/fuels will be delayed because of infrastructure and low household incomes, while Russia is improving its infrastructure and sees no reason to promote alternative powertrains/fuels because of its supply of petroleum.

Innovation Efforts

The Indian government has initiated the Hybrid Development Project to develop hybrid vehicles to be used during the Commonwealth Games in India in 2010. The project uses the combined talents of all the major domestic manufacturers of both 4 wheelers and 2 wheelers. This is a private-public partnership with the government providing 50 percent of the funding. The vehicles are expected to run on CNG and electricity. Since the government reduced the high tax for importing hybrid vehicles, many global manufacturers are readying their hybrid vehicles for export to India.

IHS Global Insight (IHS Global Insight, 2010) sees a variety of alternative powertrains/fuels used in India's future. By 2020, they expect only the following powertrains/fuels to represent the alternative powertrains/fuels: CNG, diesel/CNG, Diesel/electric hybrid, pure electric, gas/CNG, gas/electric hybrid, and gas/LPG, with gas/electric hybrid as the main alternative powertrains.

Fleet Turnover Analysis

Because India has a relatively large fleet, very low penetration of alternative powertrains/fuel in the short term, and less pressure to meet GHG emissions regulations, our predictions for India's adoption of alternative powertrains are lower than most other countries in our analysis. As shown in Table 7 and Figure 19, our analysis shows that only 36 percent of the fleet would be turned over by 2050 in the less aggressive model, 51 percent of the fleet would be turned over in the moderately aggressive model, and 68 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 7
Indian fleet turnover statistics.

Indian fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	3%	3%	3%
Alternative powertrains/fuel: 2015	3%	6%	10%
Alternative powertrains/fuel: 2020	5%	8%	15%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	Beyond 2050	Beyond 2050	2050
Fleet turned over by 2050	36%	51%	68%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

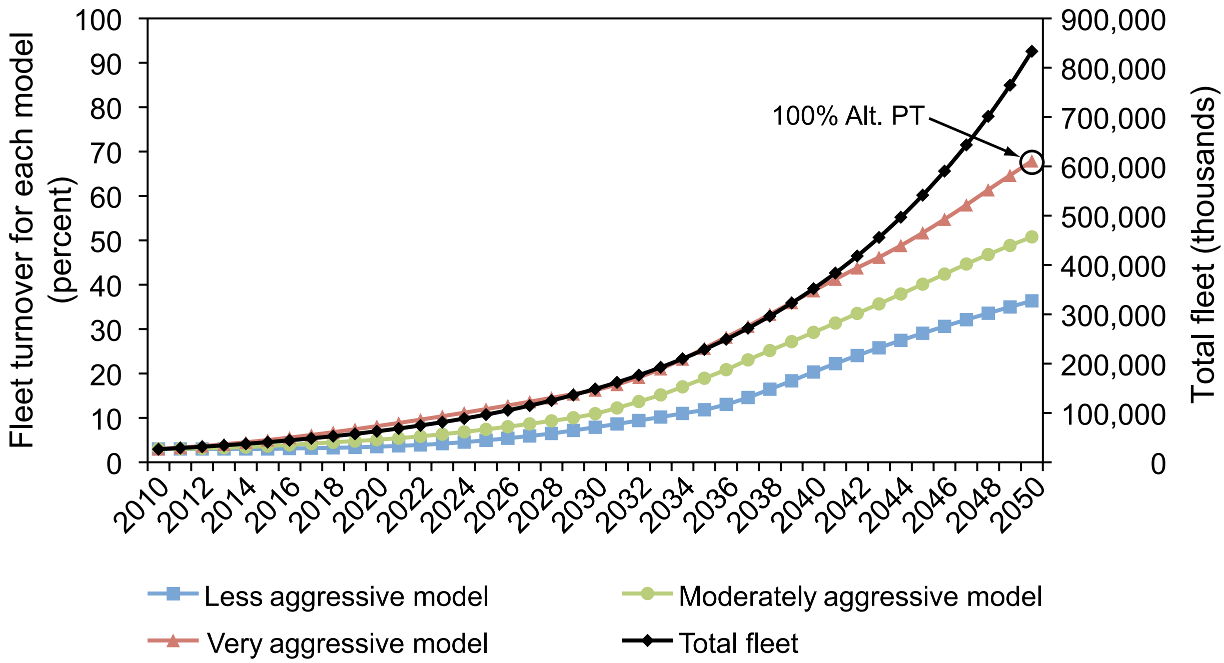

Figure 19. Turnover of the Indian fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

China: Managing Explosive Growth

Because of its explosive growth, China is quickly moving from the early stage and into the middle stage of becoming an automotive market. China is unique among the current automotive economies because it has a growing middle class that has saved money and is ready to purchase the vehicles produced by the foreign and domestic auto companies. In fact, China became the largest auto market in the world in 2009, passing the United States. China also has leaders who are concerned not only about developing their domestic brands, but also managing their dependence on foreign oil and vehicle emissions. They have also put in a lot of infrastructure to support the growth of the industry, and are now working on improving secondary roads in the interior of the country in order to spark sales in that part of the country. With a vehicle fleet of about 38 million vehicles, China is trying to balance market development by supporting domestic automakers with energy security by supporting development of alternative powertrains/fuels. Its explosive growth, which is made up almost entirely of gasoline and diesel vehicles, means that the fleet it will need to turn over is growing larger every year, and the sooner they introduce alternative powertrains/fuels into the fleet then the sooner the fleet will turn over, thereby creating more energy security. China's leaders understand this challenge and are creating policies to support sales as well as provide R&D monies for the development of the alternative powertrains/fuels.

Regulatory Efforts

With China having five cities that have qualified as five of the top ten cities with the worst air pollution and estimates of a 150 million-vehicle fleet by 2020 (Booz & Company, 2010), China's leaders understand the need to curb emissions and increase alternative powertrains/fuels. Since 2006, when China unveiled its 11th Five Year Plan (2006-2010), its 863 Program (State High-Tech Development Plan) has promoted the support platform for the transition to New Energy Vehicles (Booz & Company, 2010). In response to the global financial crisis, China provided 34 percent of its stimulus (US$218 billion) to Green Technologies, of which 4 percent is targeted to low-carbon vehicles (UNEP, 2009). In the short term, they are encouraging gasoline-powered passenger vehicles with less than 1.5 liter engines to become 40 percent of the new vehicle fleet, and they are building capacity for 500 thousand alternative powertrain/fuel vehicles for 5 percent of sales (Booz & Company, 2010). We expect the government's promotion of alternative powertrains/fuels to expand under the 12th Five Year Plan (2011-2016).

Innovation Efforts

Because of the government support for more fuel-efficient vehicles, China's domestic manufacturers, as well the many global manufacturers in China, are developing and selling vehicles with alternative powertrains/fuels. In particular, the domestic manufacturer, BYD (Build Your Dreams), is focusing its R&D on hybrid and pure electric vehicles. As a designer and builder of lithium-ion batteries for phones and computers, BYD is putting forth a significant effort in designing the batteries for these vehicles. Combining the domestic alternative powertrains/fuel vehicles with the sophisticated New Energy Vehicles the global manufacturers can bring to China, the Chinese consumer, who seems to have money to spend, will have many choices in the relatively near future. One key issue will be the need for infrastructure innovation from the government side needed to promote electric-powered vehicles within China.

IHS Global Insight (IHS Global Insight, 2010) also sees a focus on electric and alternative fuels in China's future. By 2020, they expect only the following powertrains/fuels to represent the alternative powertrains/fuels: CNG, pure electric, ethanol/electric hybrid, gas/CNG, gas/CNG/electric hybrid, gas/LPG, and gas/electric hybrid, with the gas/electric hybrid dominating the alternative powertrains/fuels.

Fleet Turnover Analysis

China's explosive growth in new vehicle sales has enlarged the fleet and populated it with new, more fuel-efficient vehicles. But these vehicles still rely on gasoline and diesel fuel and few involve alternative powertrains such as hybrids. China's concentrated push to move away from its dependence on foreign oil has the potential to dramatically change its fleet composition. Though the alternative powertrains/fuels are not currently available in large numbers, the government's incentives for sales and R&D for these alternatives may signal a more aggressive path to turning over its fleet. As shown in Table 8 and Figure 20,82 percent of the fleet would be turned over by 2050 in the less aggressive model, 92 percent of the fleet would be turned over in the moderately aggressive model, and 99 percent of the fleet would be turned over in the very aggressive model in 2050.

Table 8
Chinese fleet turnover statistics.

Chinese fleet	Less aggressive	Moderately aggressive	Very aggressive
Alternative powertrains/fuel: 2010	1%	1%	1%
Alternative powertrains/fuel: 2015	6%	7%	10%
Alternative powertrains/fuel: 2020	10%	10%	25%
Year new vehicle sales equal 100 percent alternative powertrains/fuel	2050	2044	2028
Fleet turned over by 2050	82%	92%	99%
Year fleet turns over to all alternative powertrains/fuel	Beyond 2050	Beyond 2050	Beyond 2050

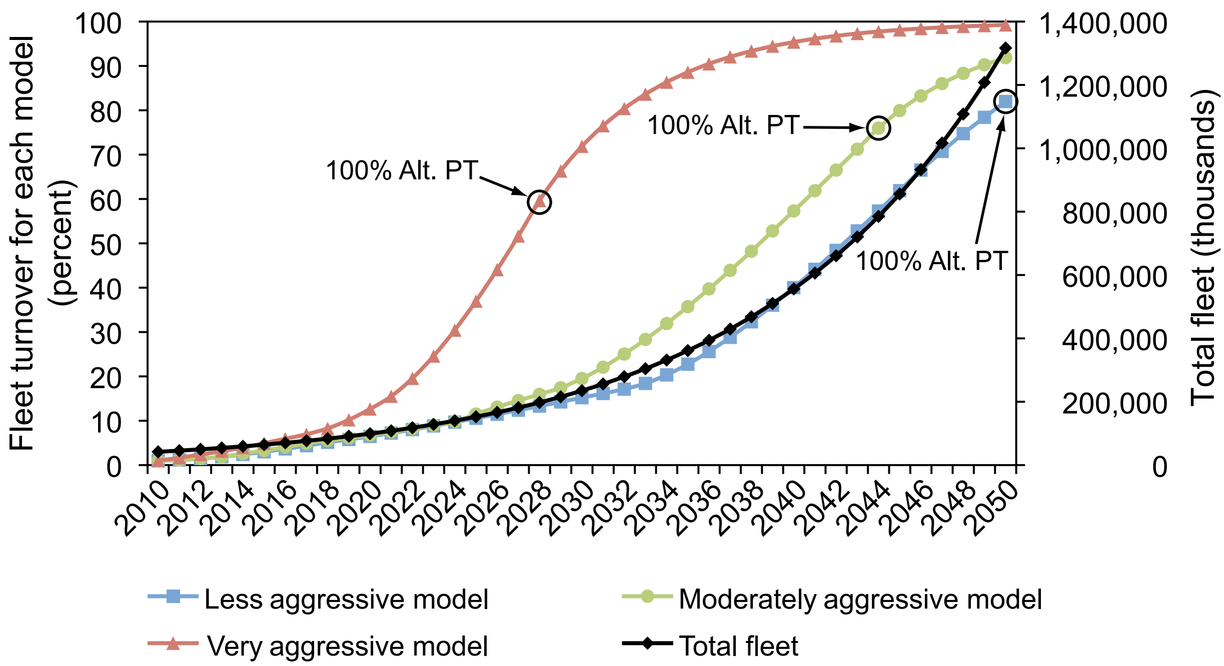

Figure 20. Turnover of the Chinese fleet (IHS Global Insight, 2010; Euromonitor International, 2010).

Conclusions

A U.S. Department of Energy program manager recently stated that when introducing a new automotive powertrain technology into a developed market such as the United States, it takes 20 years to bring it to the market, 20 years to get all the old technology out of all the vehicles, and a minimum of 30 years to get the full benefits of the introduction (P. Davis, personal communication, February 20, 2010). The governments, the energy companies, and the auto companies all understand that they will have years to adjust to the evolution to alternative powertrains/fuels, but the challenge of turning over an entire fleet is daunting to even evolutionary thinking. Our analysis of fleet turnover in this report shows the challenge of fleet turnover to alternative powertrains/fuels that include some of the fuels that countries are trying to displace (e.g. hybrid engines that use gasoline or diesel fuel). Eliminating hybrids from the equation would make the transition to alternative powertrains/fuels possibly a 75 to 100 year venture!

When we look at the fleet turnover statistics for the countries in our study in Table 9, we see countries with very different forms of government, social structures, natural resources, and topographies. We also see that if countries take a less aggressive approach to turning over their fleet to alternative powertrains/fuels than they have currently stated, many of them will still be very dependent on foreign oil by 2050. Most countries can, with a moderately aggressive approach, turn over most of their fleets, and most of the countries that take a very aggressive approach can meet such a goal by 2050. Yet even in the automotive industry with its long lead times for vehicle development, 40 years is a long time. However, when countries demand that automotive companies introduce new technologies that reduce dependence on foreign oil or reduce greenhouse gas emissions, this is exactly the type of timeframe they must consider.

Table 9
Overall fleet turnover statistics.

Fleet	Percent of fleet turned over by 2050		
	Less aggressive	Moderately aggressive	Very aggressive
United States	77%	84%	93%
Western Europe	69%	83%	90%
Japan	72%	88%	93%
South Korea	60%	80%	87%
Brazil	95%	98%	99%
Russia	64%	75%	83%
India	36%	51%	68%
China	82%	92%	99%

As one might expect, the sooner a country can have 100 percent of its new vehicle sales as alternative powertrains/fuels, the sooner it can turn over its fleet, though completely turning over the fleet is an elusive goal. It is not just a matter of making every one of the new vehicles sold each year more fuel efficient; it is also a matter of replacing the vehicles that are already on the road with vehicles that are more fuel efficient.

In order to succeed in this endeavor, a country must be steadfast in moving towards its goal. Consistent policies over a long period of time can make the turnover process more efficient, allowing all the parties involved (governments, energy companies, auto companies, and consumers) time to adjust to the change taking place. Of course, countries cannot control all the factors involved in transitioning to alternative powertrains/fuels. Externalities such as wars, oil embargos, recessions, or environmental disasters can hinder or stimulate the effort. But if countries have a sense of urgency in their need to move to alternative powertrains/fuels, they will generate the momentum within their country to reach their goal. Keeping up the momentum over a long period of time is not easy. There will no doubt be some stops and starts in the process, but understanding and accepting the need to change and beginning the process are the necessary elements of any major transition.

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