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Achieving a sustainable automotive sector in Asia and the Pacific: Challenges and opportunities for the reduction of vehicle CO_2 emissions

*By Masato Abe, PhD**

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* Economic Affairs Officer, Private Sector and Development Section, Trade and Investment Division, Economic and Social Commission for Asia and the Pacific.. The author is grateful to Marc Proksch and Hongpeng Liu for their comments and inputs, and to Natthika Charoenphon and Panjai Limchupong for formatted the manuscript. The technical support of the ARTNeT secretariat is gratefully acknowledged. The opinion, figures and estimates in this paper are the responsibility of the author and should not be considered as reflecting the views or carrying the approval of the United Nations or ARTNeT. Any errors are the responsibility of the author, who can be contacted at abem@un.org.

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Executive summary

To mitigate the level of vehicle carbon emissions in the next few decades, effective policy and technical options must be considered by the governments and automakers (and their suppliers) within Asia and the Pacific, where rapid development of the automotive sector is expected. Various factors and players, however, are also driving carbon emissions from vehicles in the region, leaving policymakers with complicated coordination tasks. At the same time, the implementation and development of most carbon emission reduction initiatives and technologies will not be cost-effective at economies-of-scale without some form of combination of support mechanisms for the sector's investments. Such mechanisms should include economic incentives and regulatory regime improvements, possibly covering taxation, subsidies, industrial standards, vehicle regulations and transport infrastructure, while additional interventions may be necessary with regard to soft issues, such as behavioural changes and demand management, working primarily with consumers.

Cutting vehicle carbon emissions also requires a region-wide approach to addressing all the critical factors while also dealing with all the key stakeholders. In this sense, for Asia and the Pacific an integrated policy approach is needed contains various measures, with priority being given to investment in energy efficient and low-carbon vehicles, in order to meet short- and long-term economic and sustainability targets of the region. The integrated approach for the region should set long-term targets for carbon emission reductions while implementing various policy measures that would reduce uncertainty and risk in the automotive sector as well as giving automakers financial incentives to invest in new technologies.

This working paper analyses the contribution of the Asia-Pacific automotive sector to greenhouse gas (GHG) emissions, and the challenges and opportunities facing the sector in efforts to reduce those emissions, primarily carbon dioxide (CO_2). The main purpose of this paper is to identify recommendations for appropriate policies and strategies as well as for regional cooperation, to ensure that future developments in the automotive sector contribute to mitigating and adapting to climate change. However, the contribution must be made without affecting the economic development of individual countries, and should be based on cooperation between the automotive sector and governments in the region.

Introduction

The challenges and opportunities facing the Asia-Pacific automotive sector in reducing GHG emissions are becoming a critical issue. Therefore, the main focus of this working paper is to identify recommendations for appropriate policies and strategies as well as for regional cooperation, to ensure that future developments in the automotive sector contribute to mitigating and adapting to climate change. However, any such contribution must not affect the economic development of individual countries, and should be based on cooperation between the automotive sector and governments in the region.

Within this context, special emphasis is placed on the drivers of vehicle CO_2 emissions and available technological options for reducing emissions in the automotive sector of the region which is facing increasingly intensified competition in developing environmentally-friendly and fuel-efficient vehicles. Based on this analysis, the future direction of the automotive sector is presented, including a policy and regulatory framework for effectively reducing CO_2 emissions. Modalities for regional cooperation are also proposed. Although this paper primarily focuses on the Asia-Pacific region, given the industry's interregional structure its global perspectives are also covered where appropriate.

The methodology for this study involved the use of extensive and diversified research resources on the development of the automotive sector and the evolution of the sector's CO_2 emissions. Qualitative and quantitative data were utilized in assessing the status of the automotive sector and its CO_2 emissions. The study presents technological options and proposes policy changes with the purpose of reducing CO_2emissions from the automotive sector at the global and regional levels.

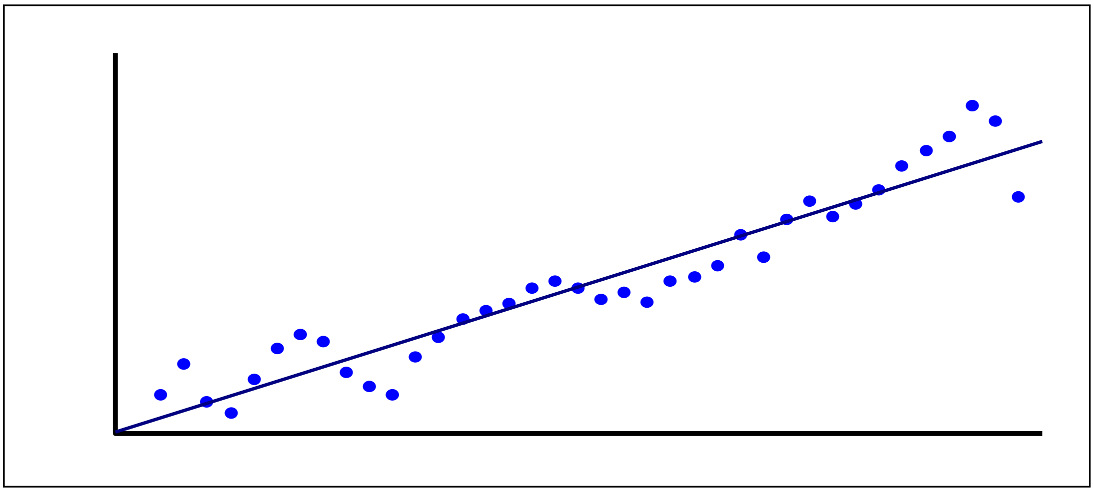
Section 1 describes the development of the Asia-Pacific automotive sector mainly in terms of its global and regional production and export capacities, and dynamism. Section 2 analyses CO_2 emissions from the automotive sector and their impact, based on emission sources and vehicle life-cycle CO_2 emissions, followed by future scenarios of vehicle CO_2 emissions. In section 3, technical options for reducing CO_2 emissions from the automotive sector are explored, based on the latest industrial data. Available policy options for countries in the Asia-Pacific region are presented in section 4, covering in particular five critical issues: (a) taxation; (b) fuel-efficiency standards; (c) fuel-efficient vehicles and alternative fuels; (d) traffic management and infrastructure; and (e) training and awareness raising. Section 5 provides recommendations for an integrated policy approach for Asia and the Pacific).

1. Developments and trends in the automotive sector

A. Global developments

The transport sector, especially cars, is the second largest contributing sector to GHG emissions after the power sector, according o the International Energy Agency (IEA) (2009a). The sector has been increasing automobile production worldwide in recent decades, although short-term declines in production have been also observed from time to time (figure 1). Between now and 2050 the global car fleet is expected to triple, with more than 90 per cent of this growth occurring in non-OECD developing countries (UNEP, 2009).

Figure 1. Annual global production of cars, trucks and buses, 1972-2010



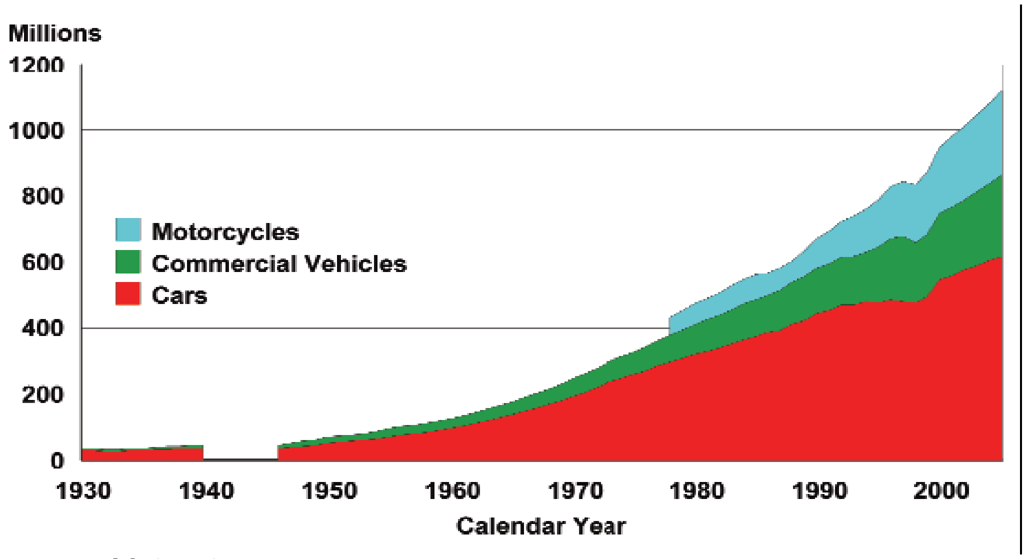
Source: Walsh, 2009, updated with data from the International Organization of Motor Vehicle Manufacturers (OICA) production statistics (accessed 7 June 2010).

In 2007, the number of vehicles produced worldwide reached 73.3 million units, with an average annual growth rate of 1.9 per cent since 1972. Although the occurrence of the global recession caused sharp production declines in 2008 and 2009 (total production fell to 70.5 million and 61 million units, respectively) a quick recovery was observed in 2010, partly as a result of various government support schemes for new clean, fuel-efficient cars, e.g., cash for scrapping old vehicles.[1] It is likely that the global market will exceed former levels of production within a few years, as emerging markets in the Asia-Pacific region (e.g., China and India) are expected to lead production in meeting global vehicle demand (ESCAP, 2009a).

As vehicle production has been increasing and vehicles have been produced faster than the rate at which they have been scrapped, the global total of vehicles in use, including private cars, commercial vehicles and motorcycles, has also increased at a growing pace (figure 2). Since 1990, each year approximately 27 million more vehicles have come on to the roads worldwide, compared with the previous year; globally, vehicles exceeded 1 billion units in 2002 (Walsh, 2009). Private passenger cars currently account for approximately two-thirds of all global vehicles in use.

[1] To reduce CO_2 emissions from motor vehicles, focus cannot be placed only on new cars and vehicle technology. To a large extent, CO_2 emissions result from an ageing car fleet (European Automobile Manufacturers' , Association, 2007).

Figure 2. Total vehicles in use worldwide, 1930-2005



Source: Walsh (2009)

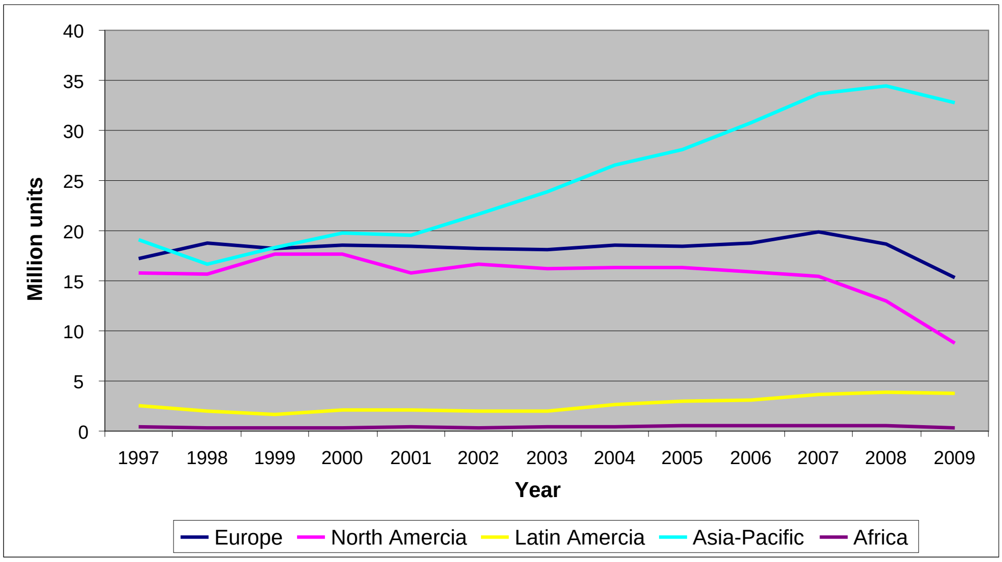
B. Developments in Asia and the Pacific

One major change that can be observed in the global automotive sector is the increasing production capacity in Asia and the Pacific. Several developing countries in the region have recently exceeded 1 million in annual car production. Emerging car producing countries in the region include China, India, the Islamic Republic of Iran, the Russian Federation, Thailand and Turkey. As a result, more than one in two new cars in the world is currently produced in the Asia-Pacific region (ESCAP, 2009a).

Three regions in the world, i.e., Asia-Pacific (mainly Japan and the Republic of Korea), Europe and North America, have traditionally been the major hubs of automobile production. While Europe and North America have experienced flat growth in production since the 1990s, the Asia-Pacific region has achieved steady production growth in line with rising FDI inflows and a strengthening of automotive value chains in the region (ESCAP, 2007). In 2008, regional production of automobiles reached 34.4 million units out of a total global production of 70.5 million units (48.8 per cent), which exceeded by far the automobile production in the other four regions of the world (figure 3). Due to the continuing economic crisis, Asia-Pacific reduced its annual production to 32.8 million units in 2009, while global production also declined to 61 million units. As a result, the region increased its share of global production to 53.7 per cent as Europe and North America struggled with sharp declines in their automobile production.

After the Asian financial crisis of 1997-1998, all subregions in Asia and the Pacific steadily increased the production of automobiles. In particular, production in East, North-East and South-West Asia soared, while South-East, Central and North Asia experienced moderate growth, although the global recession notably slowed down production in the region in 2008 and 2009 (figure 4). In fact, total motor vehicle production in East and North-East Asia, which includes China and the Republic of Korea, surpassed production in the region's developed countries (mainly Japan) for the first time in 2007.

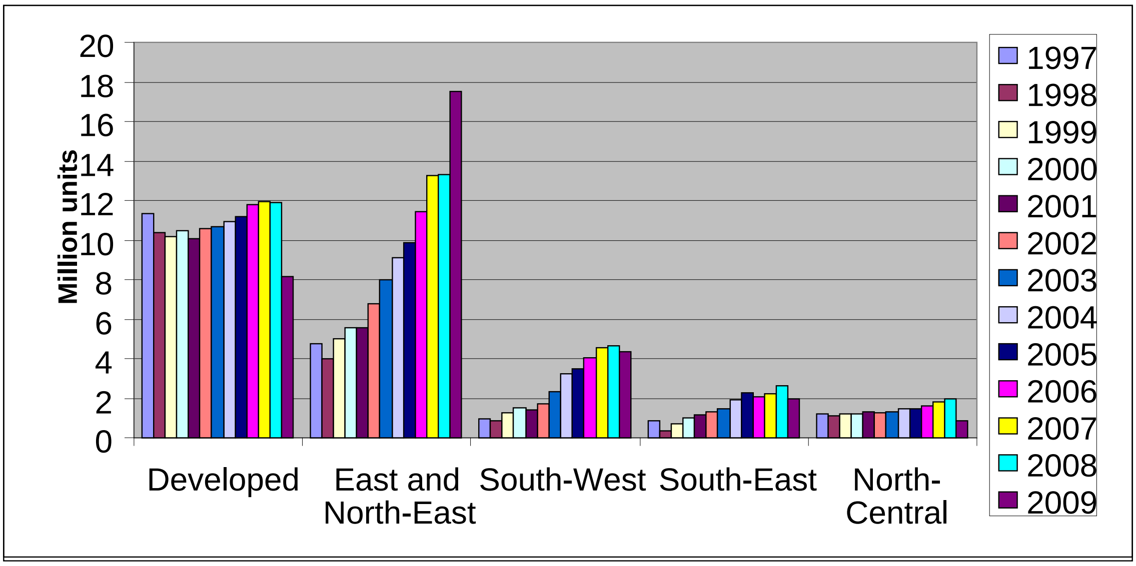
Figure 3. World production of automobiles, by region, 1997-2009



Source: ESCAP, based on data from OICA production statistics (accessed on 7 June 2010).

It is also noteworthy that, in 2009, East and North-East Asia regained growth momentum in the sector and increased automobile production by an impressive 31.5 per cent compared with the previous year. This was due solely to China's increased production, while all other subregions experienced a slump in production.

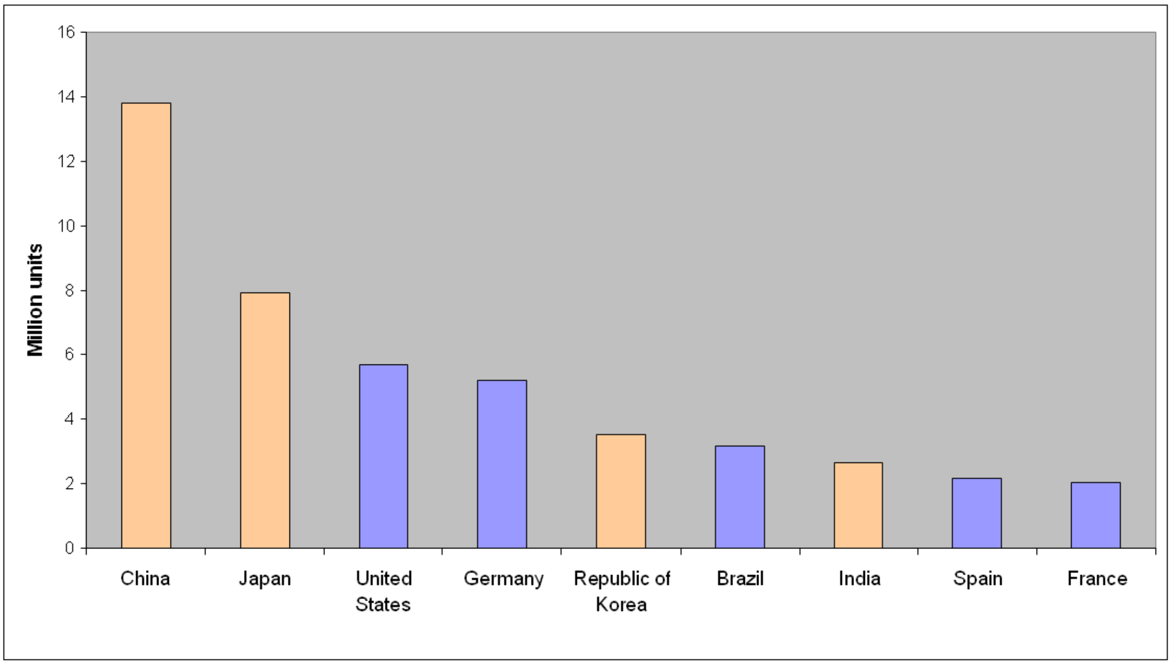
Figure 4. Production of automobiles in Asia and the Pacific, by subregion, 1997-2009



Source: ESCAP, based on data from the International Organization of Motor Vehicle Manufacturers (OICA), Production Statistics, accessed on 7 June 2010.

In 2009, four Asian countries – China, Japan, Republic of Korea and India – were listed among the top 10 automobile manufacturing countries in the world (figure 5). China and India experienced a notable development in production capacity during the 2000s as they increased their annual vehicle production by an average 24 per cent and 15 per cent, respectively.[2]

Figure 5. Top 10 automobile manufacturing countries, 2009



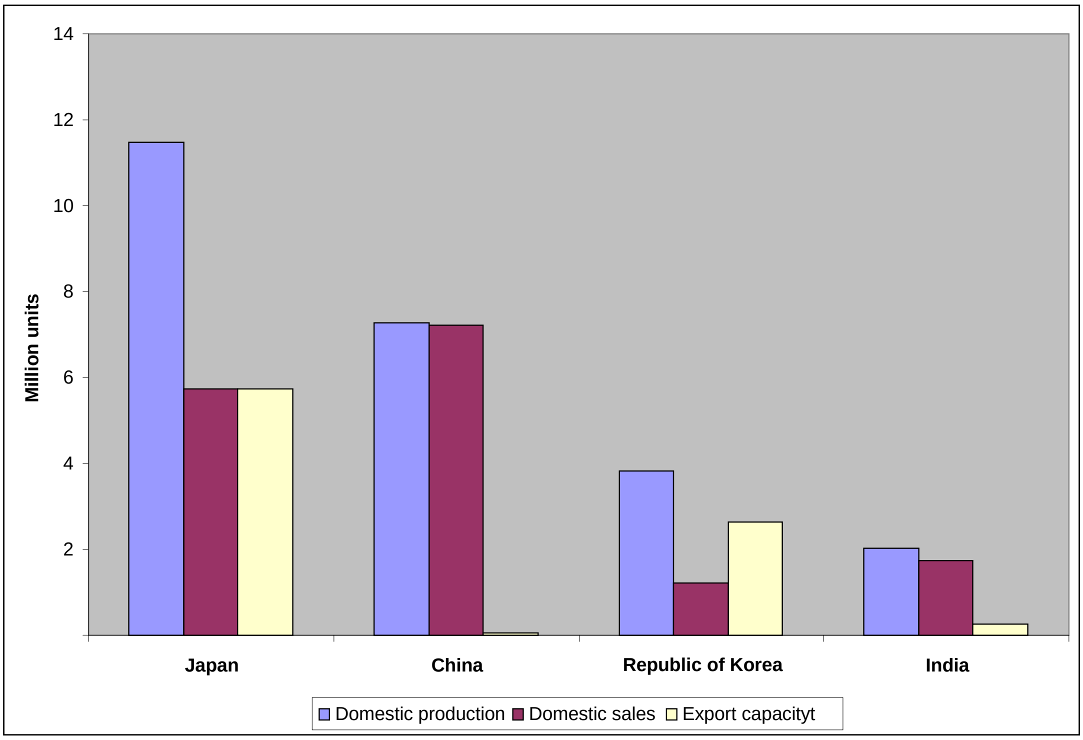
Source: ESCAP, based on data from OICA production statistics, accessed on 7 June 2010.

Figure 6 illustrates the automobile production capacity, domestic sales and estimated export capacity of China, Japan, the Republic of Korea and India in 2006, prior to the financial recession. The figure highlights the fact that Japan developed the largest capacity for exports, in terms of units, among the four countries, followed by the Republic of Korea, while the Republic of Korea built nearly 70 per cent of its production capacity for export, compared with Japan's 50 per cent. India recorded a moderate level of export capacity, although it was large compared to the size of the country's economy. China almost matched its production capacity with domestic sales, fulfilling its rapidly growing domestic demand.

Because of the global decline in automobile demand during 2008 and 2009, Japan and the Republic of Korea were the most adversely affected due to their large export capacities, and production dropped by 32 per cent and 14 per cent, respectively, in those two countries in 2009 from the pre-recession production level of 2007 (OICA, 2010). In contrast, China and India, whose automotive sectors mainly serve the domestic market, faced only a moderate impact compared to other major car export countries, and are currently contributing to the rapid recovery of the automotive sector of the region.

[2] Calculation based on the OICA database.

Figure 6. Pre-crisis production, domestic sales and estimated export capacity of the major automobile-producing countries in Asia and the Pacific, 2006



Source: ESCAP, based on data from OICA, 2010, and Economist Intelligence Unit, 2009..

In conclusion, the automotive sector has developed massive production bases in the Asia-Pacific region, turning the sector into a prominent player in the economic development of the region. However, it also implies that the automotive sector is emerging as a major contributor to GHG emissions in the region. Therefore, the sector must adopt appropriate measures in collaboration with governments in order to achieve a sustainable, long-term reverse in this trend.

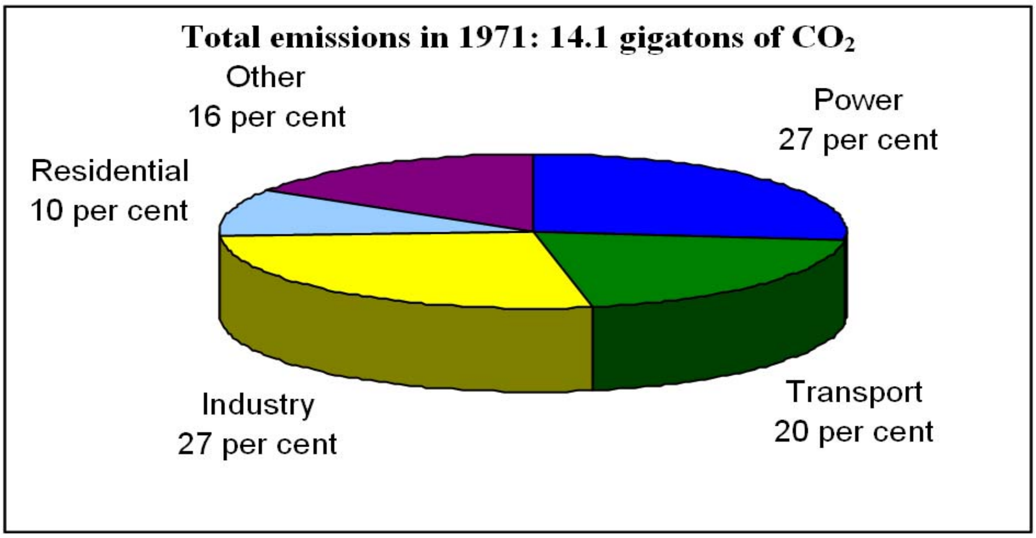
2. Contribution of the automotive sector to CO_2 emissions

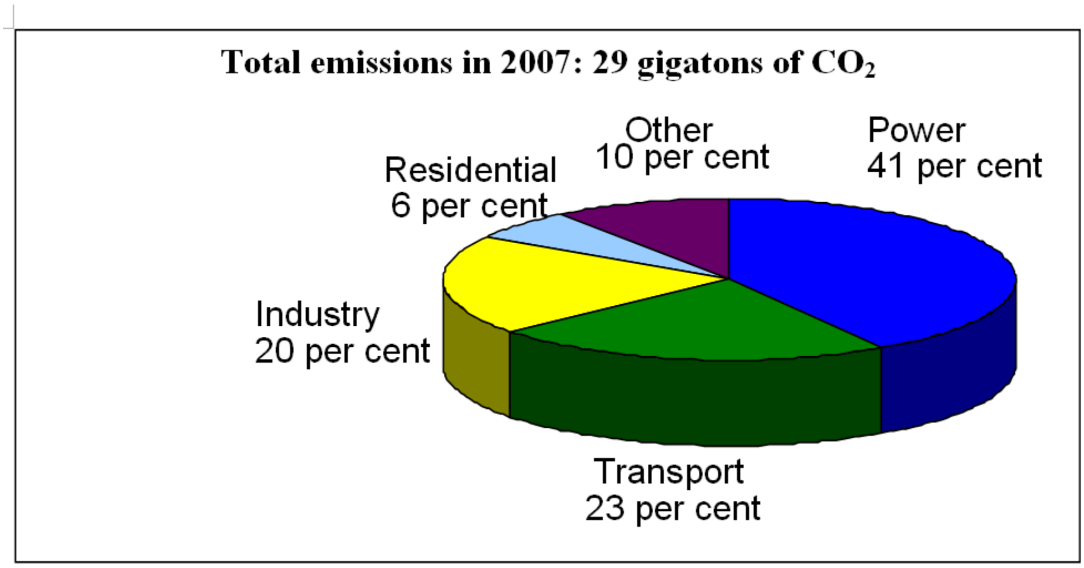
A. Automotive CO_2 emissions: An overview

Automobiles are a significant contributor to CO_2 emissions. As more and more people in developing countries demand more and better mobility in parallel with their socio-economic development, the number of vehicles in the world as well as in the Asia-Pacific region is projected to rise rapidly, offsetting progress already made in reducing fuel consumption and therefore vehicle CO_2 emissions.

Global CO_2 emissions from all sources more than doubled from 1971 to 2007, to reach 29 gigatons (figure 7). Transport, comprising ocean, rail, air and road transportation for both passengers and freight, is the second-largest source of CO_2 emissions after the power sector (i.e., electricity and heat generation), emitting approximately 23 per cent of global CO_2 emissions in 2007. The three major CO_2 emission contributing sectors, i.e., power, transport and industry, accounted for 84 per cent of global CO_2 emissions in 2007. The emissions in the transport sector also increased at a faster rate than total global emissions (45 per cent versus an average 38 per cent between 1990 and 2007) (IEA, 2009a).

Figure 7. World CO2 emissions by sector, 1971 and 2007





Source: International Energy Agency, 2009a.

Table 1 presents total national CO_2 emissions and emissions by sector in 1980 and 2005 for selected Asia-Pacific countries. It shows that the shares of the transport sector in emissions vary from country to country with some, such as Bangladesh, China, India and Mongolia, having smaller shares while other countries such as the Philippines and Sri Lanka have recorded high shares. While all countries increased their total CO_2 emissions between 1980 and 2005, the transport sector shares of total national CO_2 emissions increased in the Republic of Korea, the Philippines and Viet Nam, decreased in India, Indonesia, Pakistan and Sri Lanka, and remained more or less stable in Bangladesh, China, Malaysia, Mongolia and Thailand. Because the transport, power and industry sectors are the three main contributors to national CO_2 emissions, changes in the magnitude of the emissions from the other two sectors, particularly the power sector, have a considerable impact on the transport sector's share of national CO_2 emissions. For example, despite the increase in transport sector emissions, the share of the sector in the national total in

China and India is significantly smaller than that of most countries in the region; this is mainly because power generation in these countries is heavily reliant on emission intensive fuels, mainly coal (Timilsina and Shrestha, 2009).

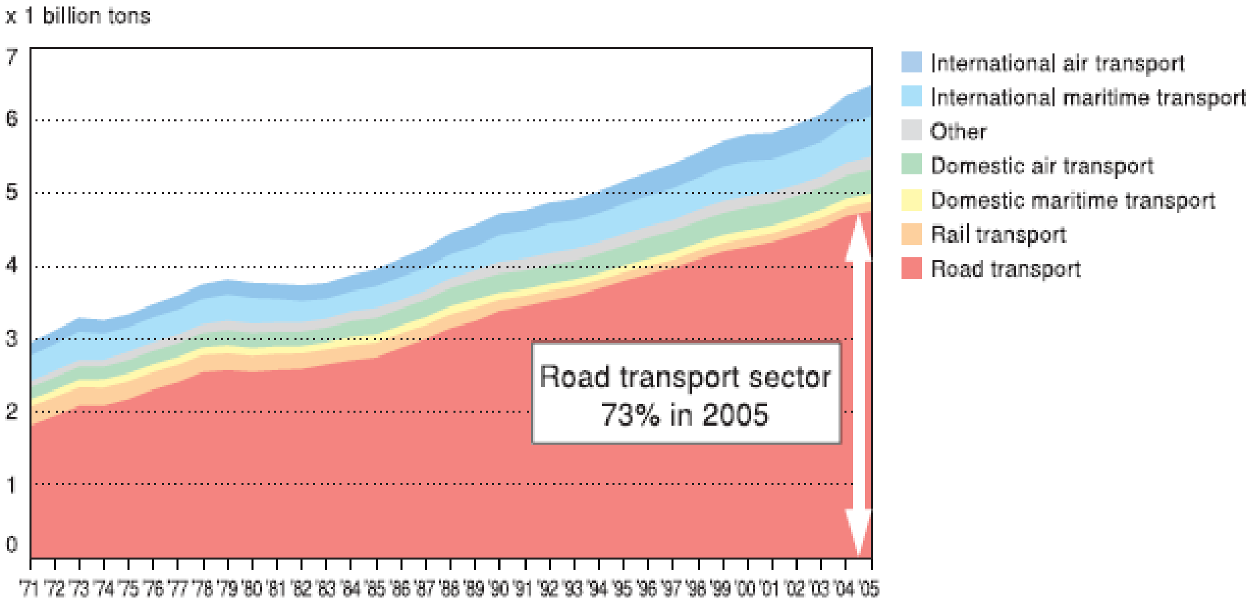
Automobiles, including passenger and commercial vehicles, are the principle industry in the transport sector. CO_2 emissions from the automotive sector have grown significantly in the past few decades. IEA (2007) estimated that 73 per cent of CO_2 emissions in the transport sector could be attributed to automobiles in 2005, with maritime and air transport some way behind at approximately 12 per cent and 10 per cent, respectively; this indicates that approximately 16 per cent -17 per cent of global man-made CO_2 emissions come from automobiles (figure 8). In particular, household car use alone accounts for much of the automotive CO_2 emissions, which have been growing by approximately 1.5 per cent annually since 1971.

Table 1. CO_2 emission mix by sector in selected countries in Asia and the Pacific, 1980 and 2005

Country	1980					2005				
	Total	Power	Industry	Transport	Other	Total	Power	Industry	Transport	Other
	(Mt of CO_2)	(%)	(%)	(%)	(%)	(Mt of CO_2)	(%)	(%)	(%)	(%)
Bangladesh	6	21	41	14	24	36	35	29	12	24
China	1 503	20	51	6	23	5 060	48	37	7	9
India	292	26	39	19	16	1 147	52	30	8	10
Indonesia	69	10	39	26	26	341	28	39	22	11
Republic of Korea	122	20	32	12	37	449	35	31	19	15
Malaysia	23	32	34	28	6	138	33	35	28	3
Mongolia*	12	48	25	11	16	10	70	8	12	10
Pakistan	26	16	37	25	22	118	30	37	22	11
Philippines	32	27	39	15	18	76	37	19	37	7
Sri Lanka	4	8	22	55	26	12	28	16	45	11
Thailand	34	33	23	28	26	214	30	37	26	7
Viet Nam	14	24	36	14	26	80	24	37	25	14

Source: Timilsina and Shrestha, 2009.
* Data for 1985 used instead of 1980.

Figure 8. Estimated global CO2 emissions by transport mode, 1971-2005



Source: Japan Automobile Manufacturers Association (JAMA), 2008.

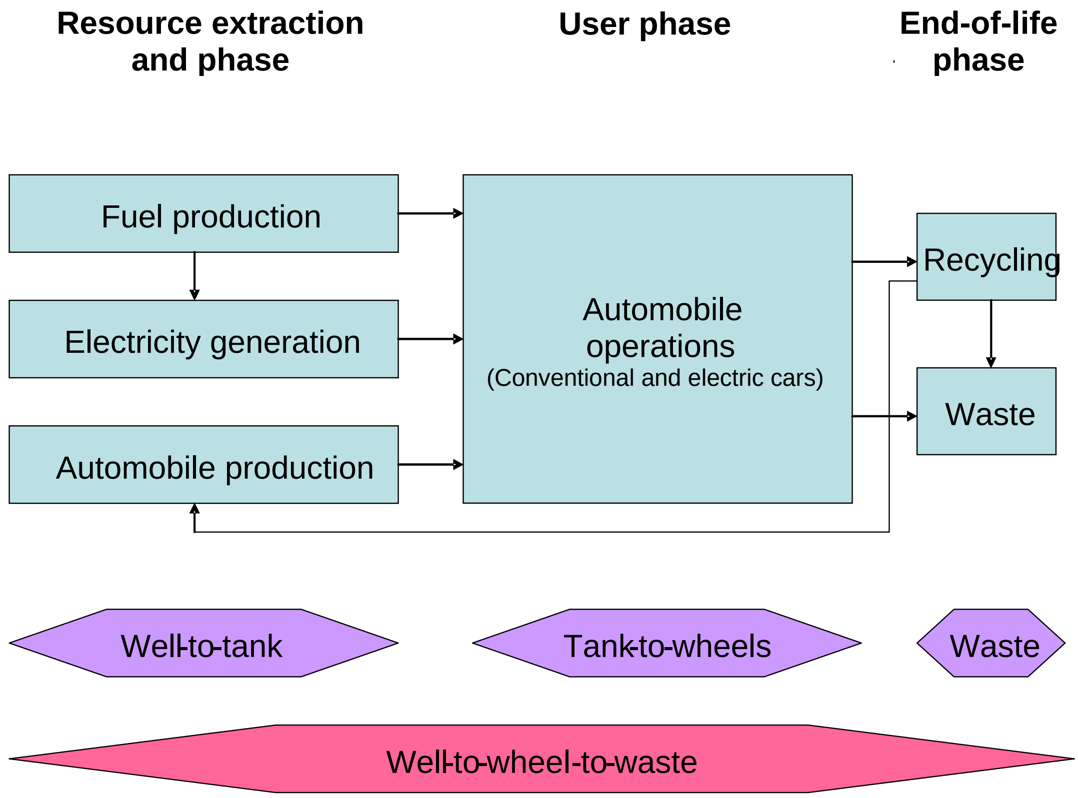
Assessed in terms of emission intensity per mt-km, maritime and rail transport are the most CO_2-efficient modes of transportation, while air transport is highly CO_2 intensive. According to the World Economic Forum (WEF) (2009), the CO_2 intensity of maritime and rail transportation is around one-sixth of that of automobiles – or one-hundredth of that of airfreight. A continuing shift to more globalized supply chains, together with the recovery from the global economic crisis, will likely lead to increased CO_2 emissions from the transportation sector, particularly the automotive subsector, unless fossil fuels can be economically replaced by renewable energy sources any time soon.

B. Life-cycle CO_2 emissions in the automotive sector

The automotive value chain comprises various activities, such as fuel production (i.e., extraction, processing, bulk fuel transportation and fuel storage, transport and distribution) and electricity generation, vehicle manufacturing (i.e., parts, components and modules, assembly and painting), vehicle transportation and storage, sales and services, vehicle use, and recycling and waste. Although there are a number of approaches that consider CO_2 emissions across the entire automotive value chain, as yet no sufficiently advanced methodology exists to draw emissions profiles for the entire vehicle life cycle (WEF, 2009). This is understandable, as the automotive sector operates in a dynamic environment with rapidly advancing technologies and a large variety of vehicle types (e.g., fuels and power trains).

However, it is possible to use the well-to-wheel-to-waste (WWW) analysis to properly assess the lifetime CO_2 emissions of vehicles with various power types (figure 9). The WWW analysis could cover three major GHG emission phases in the automotive value chains: (a) resource extraction and product production (well-to-tank); (b) vehicle use (tank-to-wheels); and (c) end-of-life (waste, including recycling) (cf. Samaras and Meisterling, 2008; TIAX LLC, 2008; and WEF, 2009). Using the WWW analysis for entire value chain CO_2 emissions, stakeholders are able to build a meaningful picture of the total life-cycle emissions of individual products and obtain an approximate idea of the CO_2 footprint of vehicles within known accuracy limits. Although the number of detailed completed studies using the WWW analysis at product level remains scarce, its use is likely to increase. It is noteworthy that the analysis would shed light on waste (and recycling) management gaps, which have received little attention as far as vehicle-related CO_2 emissions are concerned.

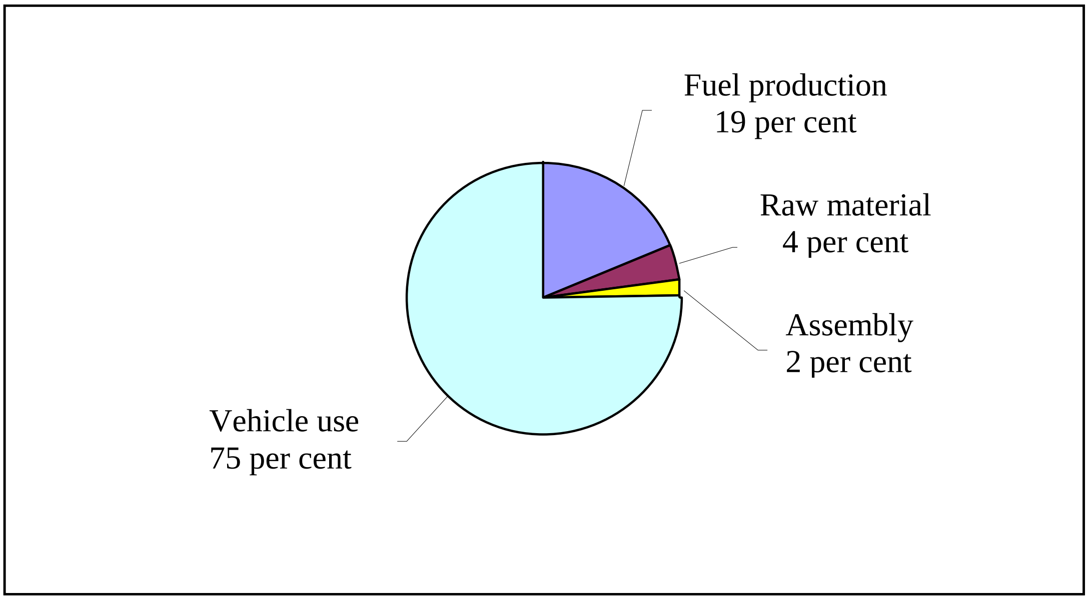
Figure 9. Well-to-wheel-to-waste CO2 emissions within automotive value chains



Similar to the analysis of life-cycle CO_2 emissions, it would be difficult to estimate the sources and their shares of CO_2 emissions very accurately throughout the automotive value chain in a rapidly changing environment. However, an earlier study estimated that direct vehicle-use CO_2 emissions make up 75 per cent of total vehicle life-cycle emissions, while emissions associated with the production of fuel consumed by vehicles make up an additional 19 per cent (Austin and Sauer, 2003). Two other emission sources, extraction and processing of raw materials used in assembly and vehicle assembly itself, account for 4 per cent and 2 per cent, respectively (figure 10).[3] This is the reason why policy interventions and automakers' voluntary actions have focused on the reduction of vehicle-use emissions. Three major CO_2 emissions programmes (i.e., those of the European Union, Japan and the United States of America) have also focused on vehicle use emissions. The European Union and Japan have had the most stringent fuel economy standards in the world, while the United States recently tightened its mandatory standards (FIA Foundation and others, undated).

[3]However, this estimate still does not cover the life-end phase, such as recycling and waste management.

Figure 10. Source of CO2 emissions across vehicle life cycles



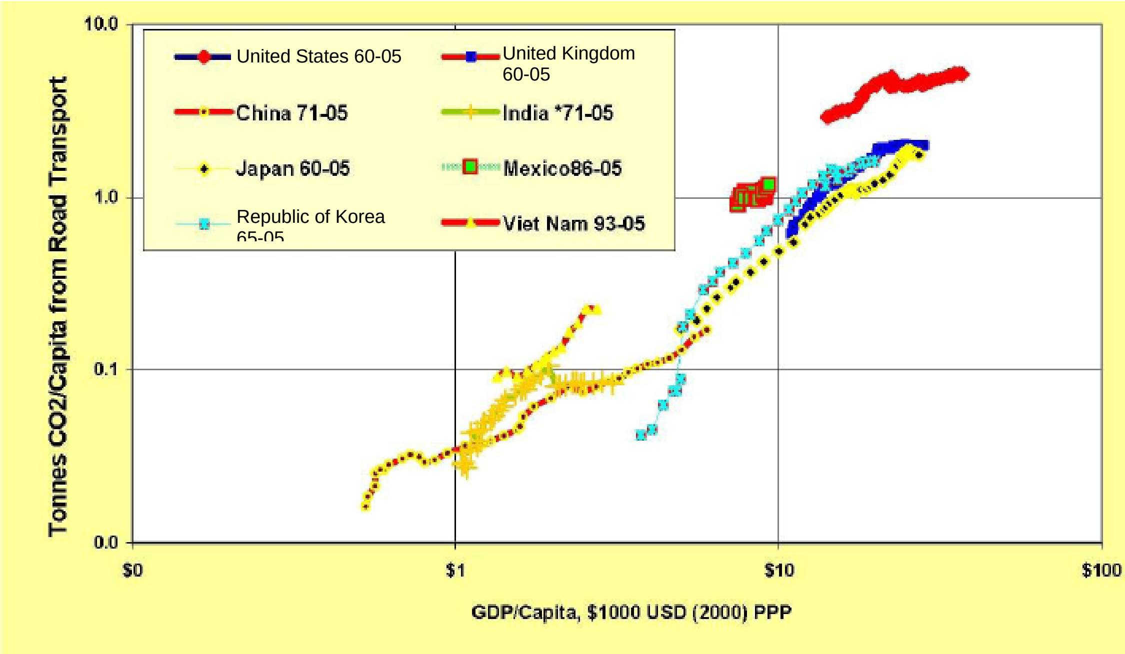
Source: Austin and Sauer, 2003.

C. Drivers of automotive CO_2 emissions

What are the main drivers of automobile production and related CO_2 emission growth? The main driver is economic growth. Although there are various drivers of vehicle CO_2 emissions, it is apparent that national economic growth plays an important role. Economic development and its associated increase in human and commercial activities increases the demand for mobility and transportation, which, in turn, requires more vehicles. The result is larger vehicle production and use, and, consequently, higher CO_2 emissions.

Figure 11 shows trends in CO_2 emissions from vehicles in use plotted against GDP per capita in 2000 United States dollars converted from original currency at purchasing power parity for selected countries, including five countries in Asia and the Pacific, namely China, India, Japan, Republic of Korea and Viet Nam. Increases in CO_2 emissions per capita are clearly observed in line with the growth of incomes per capita. It is also obvious that at any given level of per capita GDP there is a considerable association with CO_2 emissions per capita.

Figure 11. CO2 emissions per GDP per capita for selected countries

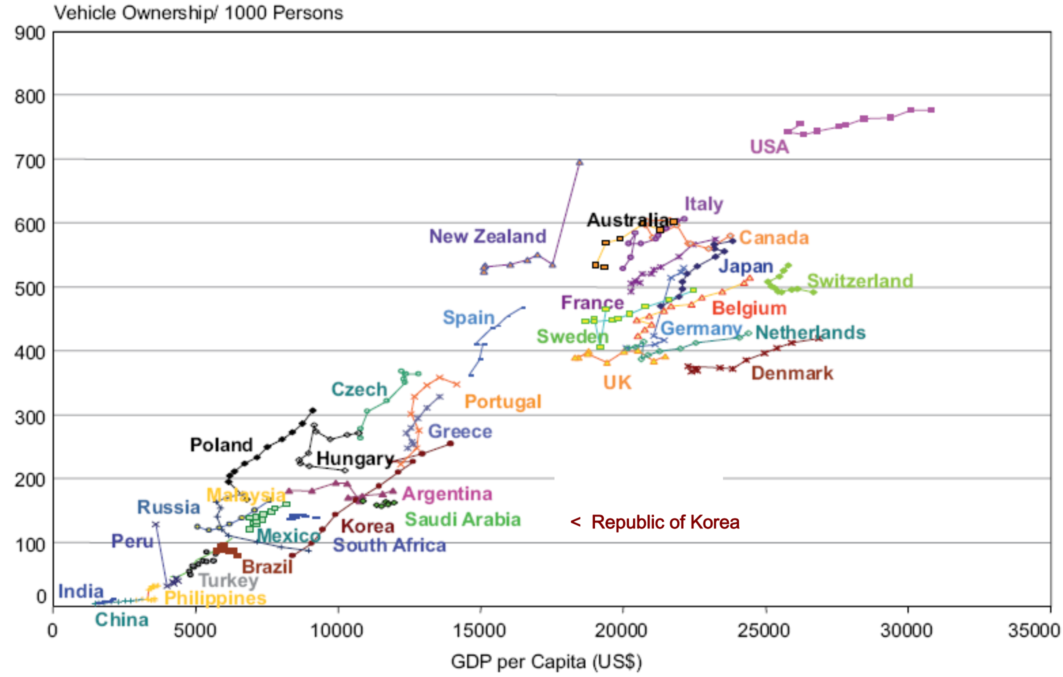


Source: Schipper (2008).

Growth in national demand for vehicles typically parallels growth in GDP per capita as national economic growth leads to increased motorization, i.e., both increases in the number of vehicles and in aggregate travel distance (figures 12 and 13). High-income countries have more vehicles per 1,000 persons than low-income developing countries.[4] However, it can be seen that the intensity of car ownership and travel distance vary considerably among countries at similar income levels, indicating that different countries may make very different choices in their national transport system (e.g., transport mode mix). In 2005, the total distance travelled by automobiles in use worldwide totalled more than 13 trillion vehicle-kilometres, 73 per cent of which was travelled by vehicles in OECD member countries. The travel ratio of passenger cars and freight vehicles was approximately 8:2 (JAMA, 2008).

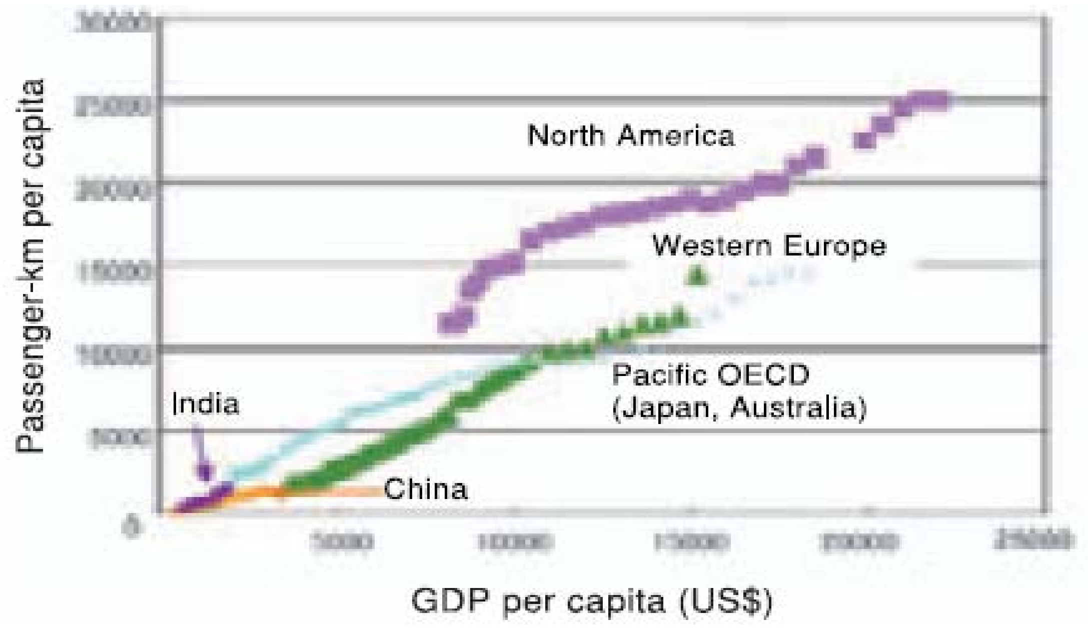
[4] Although the demand for vehicles may vary from country to country due to various reasons (e.g., geography, population density, transport mode mix and lifestyle), many studies have suggested that the saturation level of vehicle intensity in many developed countries is between 400 to 600 cars per 1,000 persons (e.g., International Panel on Climate Change, 2007; UNEP 2009; and Verband der Automobilindustrie 2005).

Figure 12. Vehicle ownership as a function of per capita income



Source: International Panel on Climate Change, 2007.

Figure 13. Passenger travel and GDP by region, 1950-1997

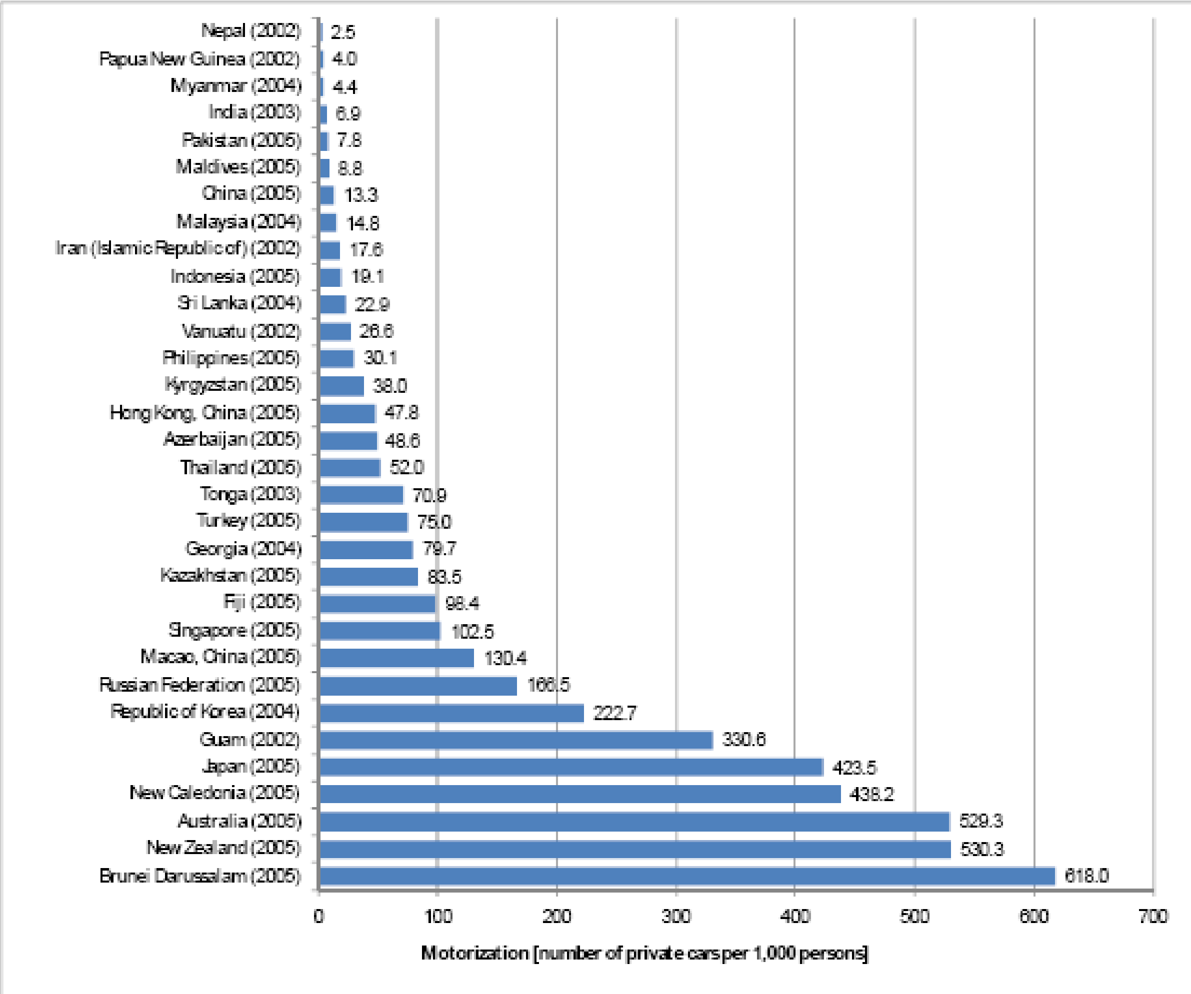


Source: JAMA, 2008.

The World Business Council for Sustainable Development (WBCSD) (2004) has noted that the number of automobiles in use worldwide has increased, as all regions of the world have experienced growth in GDP per capita, especially developing countries (WBCSD, 2004). However, the recent global recession slowed global growth dramatically. As the global economy is recovering, especially in emerging markets such as China and India, the growth trend for vehicles in use is also expected to continue. The Asia-Pacific region in particular, where rapid economic development is expected, will experience increased numbers of vehicles and longer travel distances.

However, the overall motorization level in the Asia-Pacific region is still low at an estimated 60 private cars per 1,000 persons (ESCAP, 2009b). This low current level of motorization in the region, coupled with the above-mentioned rapid economic growth, strongly indicates the likelihood of a rapid increase of the number of vehicles in the future.[5] In particular, emerging countries in the region still have a low motorization level compared with the level in developed countries. For example, motorization in India, Pakistan, China and Indonesia was still as low as 7, 8, 13 and 19 private cars per 1,000 persons, respectively (figure 14). Those populous and rapidly growing countries are expected to go through a phase of rapid motorization in the near future. A study by AC Nielson (2005) also supported the view that consumers in these countries had high car owner aspirations (table 2).

Figure 14. Motorization rates in the Asia-Pacific region, 2002-2005



Source: ESCAP, 2009b.

[5] On the other hand, five countries in Asia and the Pacific – Australia, Brunei Darussalam, Japan, New Caledonia and New Zealand – have already attained high motorization levels that are greater than 400 private cars per 1,000 persons.

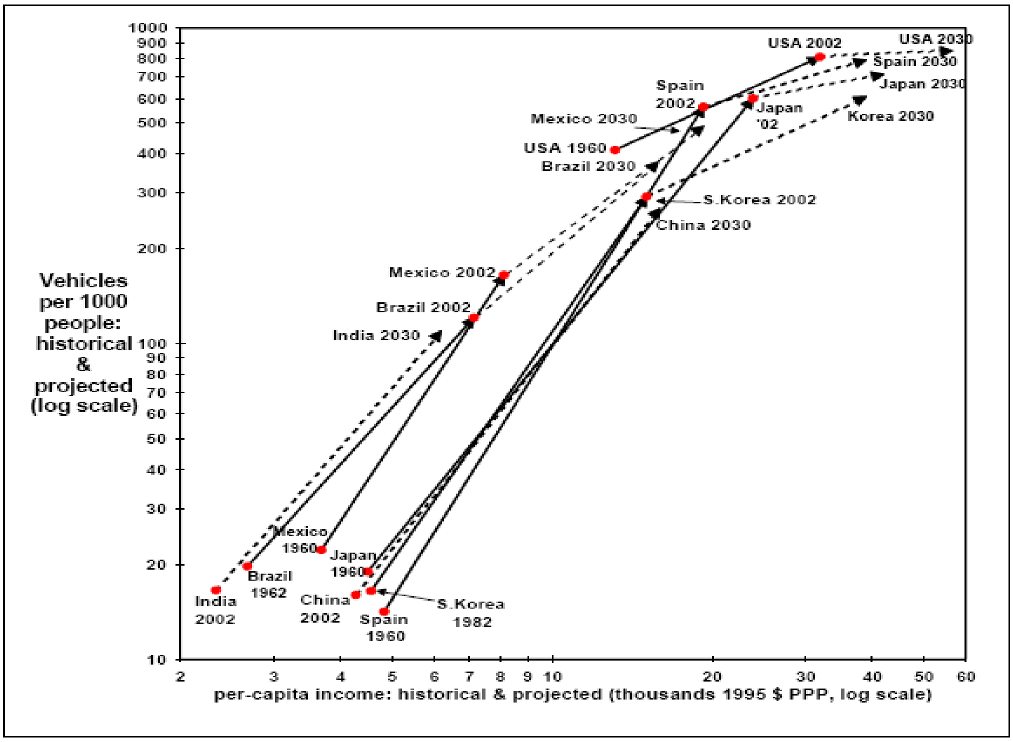
Table 2. Car ownership aspiration index

High (AI > 60%)	Medium (AI = 30 - 60%)	Low (AI < 30%)
China	Malyasia	Unites States of America
Indonesia	Singapore	sweden
Thailand	Taiwan Province of China	germany
Republic of Korea	Spain	Norway
Hong Kong, China	Australia	Austria
Phlippines	France	Netherlands
	Italy	Finland
	Unites Kingdom	Denmark
	Belgium	Japan
	Portugal	
	New Zealand	

Source: UNEP, 2009.

Dargay, Gately and Sommer (2007) and other studies (e.g., Schipper, 2008; World Bank, 2010) predicted rapid vehicle growth in both China and India (figure 15), which were calculated based on historical data and experience of other motorized countries (i.e., GDP growth and motorization of 45 countries). The results shows that many developing countries in Asia and the Pacific are currently experiencing rapid motorization similar to the motorization patterns of other countries, and will continue to do so during the next two decades. In particular, the vehicle stocks per 1,000 people of China and India are projected to reach 290 units and 100 units, respectively, by 2030. The fast rate of vehicle ownership expansion implies rapid growth in CO_2 emissions in China and India as well as other developing countries in Asia and the Pacific.

Figure 15. Projected vehicle growth for China, India, Japan, Republic of Korea and other countries



Source: Dargay, Gately and Sommer, 2007.

The rate and shape of economic growth, the primary reason driving vehicle demand, is still uncertain. However, if China and India as well as other developing countries in the Asia-Pacific region continue their high GDP growth rates, it is highly predictable that vehicle demand (both number and distance) and CO_2 emissions will grow very rapidly over the next several decades.

In addition to economic development, which spurs higher vehicle travel demand (e.g., passenger, freight, vehicle use, trip frequency and trip length), the literature has suggested that CO_2 emissions are affected by five other broad factors related to the automotive sector (cf. Environmental Defense, 2006; JAMA, 2008; OECD and International Transport Forum, 2009; and WEF, 2009). CO_2 emissions will increase as a result. Those five factors include:

(a) Transport infrastructure (e.g., road, highway, public parking and signal systems);

(b) Transport modes (e.g., car, bus, track, rail, ship and air);

(c) Fuel efficiency or economy (e.g., vehicle type, size and weight, power train and fuel consumption);

(d) Fuel CO_2 content (e.g., fuel type, quality and mix);

(e) Way of driving (e.g., driving speed and idling).

Those factors are critical to the management of CO_2 emissions from vehicles and to the automotive sector at large. Relevant interventions to specifically address these factors can be undertaken by both the public and private sectors through various means including, for example, government policies, technology development with focus on use of alternative fuels, changes in consumer lifestyle (figure 16). For example, the public sector could develop a well-designed and adequate road infrastructure to mitigate traffic congestion, which would lead to lower CO_2

emissions from vehicles in use.[6] Transport sharing and low CO_2 emission transport modes could be promoted to reduce vehicle travel demand, thus reducing the volume of vehicle CO_2 emissions. For this purpose, in various countries the transport sector already provides various fuel-efficient transport modes for passengers and freight (e.g., train and rapid bus transit systems).

Also, while automotive manufacturers can develop technologies to improve fuel economy (e.g., compact cars, hybrid cars and electric vehicles), governments and the fuel industry could promote the use of low-CO_2 biofuels. Both the public and the private sectors can promote eco-driving[7] to increase fuel efficiency, even on the basis of conventional technologies such as gasoline and diesel engines.

Figure 16. Drivers of automotive CO2 emissions

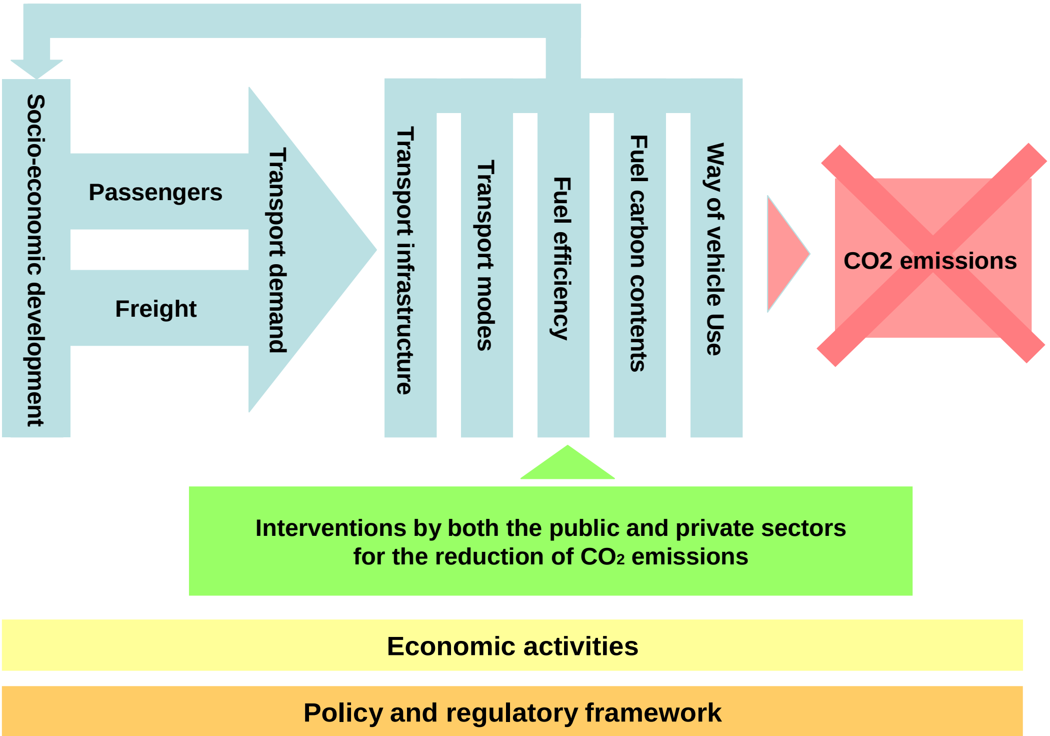


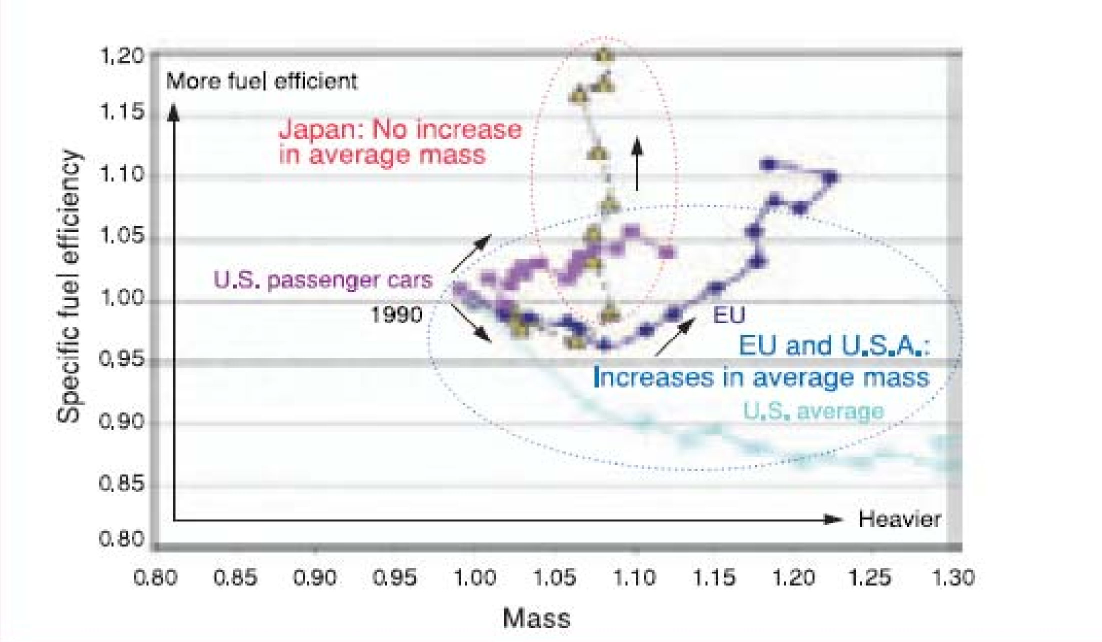
Figure 17 presents a comparison of passenger car weight and fuel efficiency among three major automobile-producing countries/regions, i.e., the European Union, Japan and the United States. It appears that the weight of passenger cars in Japan has not increased over the recent past decades. In contrast, both the European Union and the United States experienced a rise in vehicle weight during the same period as automobile manufacturers could obtain higher profits by marketing bigger and powerful cars. Figure 18 shows that CO_2 emissions rates are also substantially different among automobile segments according to vehicle size and weight. On average, the CO_2 emission rates of sports utility vehicles (SUVs) and light (pick-up) trucks are approximately twice as much as those of subcompact and compact cars. At the same time, it was

[6] Road congestion slows road traffic flow, reducing traffic travelling speed; this, in turn, decreases fuel efficiency and increases CO_2 emissions. Improving traffic flow by upgrading road infrastructure, including signal control systems, contributes significantly to reduced vehicle CO_2 emissions (JAMA, 2009a).

[7] Certain forms of driver behaviour, such as abrupt acceleration, sudden heavy breaking, frequent use of air conditioners and engine warm-up, decrease fuel efficiency and result in higher CO_2 emissions. Fuel-conserving eco-driving has been shown to increase on-road vehicle fuel efficiency by about 10 per cent. In other words, on-road CO_2 emissions decrease by an estimated 10 per cent through the adoption of eco-driving (JAMA, 2008).

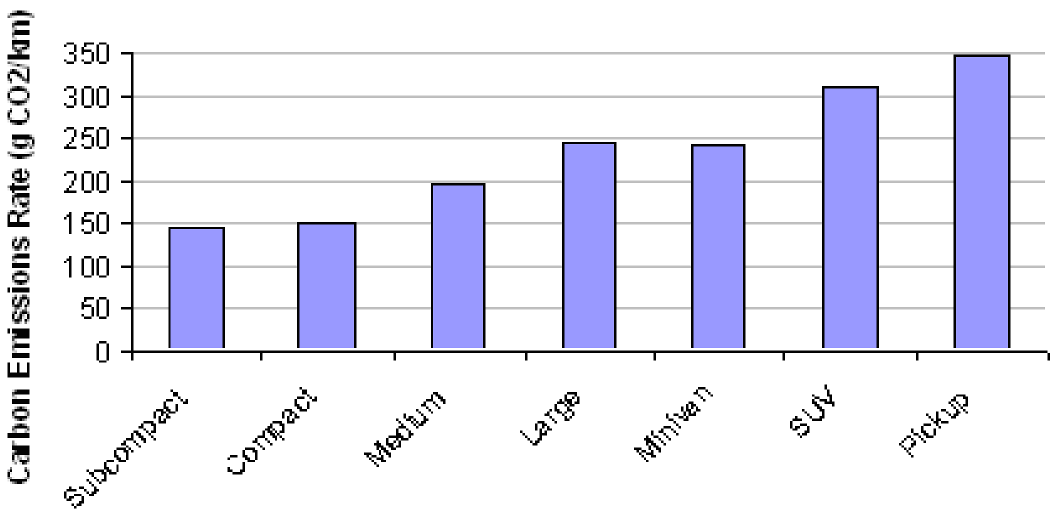
found that emission rates could vary between automobile manufacturers; such rates for mid-sized cars can vary by 50 per cent across automobile manufacturers and by 40 per cent for SUVs. This indicates substantial differences in marketing, design and technologies adopted by various automobile manufacturers (Austin and Sauer, 2003).

Figure 17. International comparison in passenger car weight: Vehicle fuel efficiency and mass



Source: JAMA, 2008.

Figure 18. Average CO2 emission rate by automobile segment, 2002



Source: Austin and Sauer, 2003.

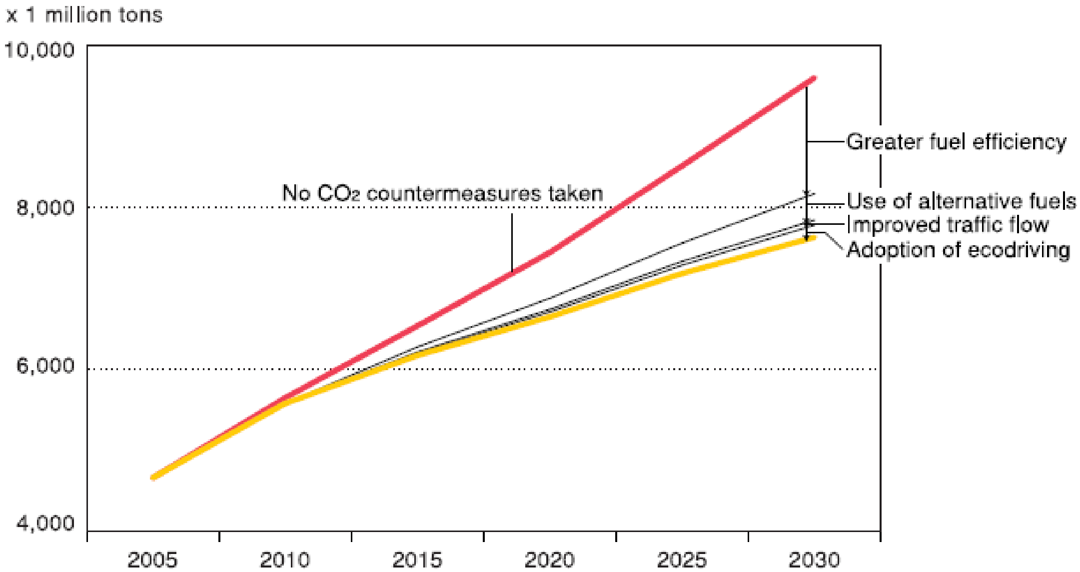
A substantial and growing proportion of CO_2 emissions is also accounted for by heavy-duty vehicles such as trucks and buses (European Conference of Ministers of Transport, 2007). A CO_2 emission study by vehicle segment in 2000 indicated that on average light trucks emitted approximately 26 per cent more CO_2 than passenger cars (United States Environmental Protection Agency, 2000). A more recent study based on 2004 data observed a wider difference between light trucks and passengers cars in CO_2 emissions, as light trucks emit 40 per cent more CO_2 than passenger cars,[8] reflecting the trend towards increasing use of larger, heavier light trucks (Environmental Defense, 2006). This strongly suggests the need for more stringent emission standards and higher fuel economy.

The above analysis points out that the increased weight (and size and power) of cars (and heavy duty vehicles such as trucks and buses) have already offset gains in fuel efficiency. Therefore, measures need to be taken to reduce vehicle weight and improve vehicle fuel economy, regardless of the market segment, to attain planned CO_2 emission targets. This may require government intervention in order to change automobile manufacturers' strategies as well as move consumer preferences away from bigger luxury cars. In various developing countries it also means improving road conditions that allow lighter passenger vehicle and reduce the need for SUVs. As long as the upward spiral of car weight and power offsets much of the impact of more efficient technology, fuel economy will not improve much in the future.

D. Scenarios for future automotive CO_2 emissions

On the basis of current growth rates of automobile production and world population as well as the observed and expected increase in the number of vehicle-kilometres travelled globally, CO_2 missions in the automotive sector worldwide are projected to increase significantly. Several studies have been conducted to estimate the degree of such an increase in the world with different results (cf. IEA, 2009a). For example, the World Business Council for Sustainable Development (WBCSD) (2004) predicted that vehicle CO_2 emissions would increase by approximately 45 per cent above the year 2000 level by 2030, and more than double by 2050. The rapid growth in the number of motor vehicles in use and the steady increase in distance travelled in developing countries are the major factors behind the actual and projected rise in CO_2 emissions worldwide (IEA, 2009a). In another example, JAMA (2008) estimated that global vehicle CO_2 emissions would increase from the 2005 level by approximately 60 per cent by 2030 unless counter-measures, including advanced drive trains, low CO_2 fuels, efficient traffic management and eco-driving are taken (figure 19).

Figure 19. Projected trends in global automotive CO2 emission volumes



Source: JAMA, 2008.

[8] It is noteworthy that the level of CO_2 emissions from light trucks are at a similar level as those from SUVs, reflecting the low fuel economy of SUVs (Environmental Defense, 2006).

The results strongly suggest that the automotive sector needs to respond quickly to climate change concerns through the adoption of sustainable practices, including the development of fuel-efficient technologies aimed at reducing CO_2 emissions, as technology and product development as well as marketing require long lead times. They also require large amounts of investment. These are challenges that require balanced, sustainable solutions, which could be developed and implemented through public private partnerships.

Improving infrastructure, public transport, fuel efficiency and driving behaviour are important elements in any strategy for reducing CO_2 emissions from vehicles, and all relevant stakeholders must participate in this effort to achieve a sustainable automotive sector in the Asia-Pacific region. In addition, there are other factors that affect CO_2 emissions from the automotive sector, including people's lifestyles and consumers' CO_2 awareness as well as fuel and energy prices. The next section examines various options for both the public and the private sectors to mitigate CO_2 emissions from the automotive sector.

3. Technical options to reduce automotive CO_2 emissions

Emerging consumer preferences, such as fuel economy and eco-friendly goods, have gained importance in the automotive sector. Consumers have become increasingly aware of the CO_2 problem and are willing to buy low-CO_2 emission cars. Changing consumer awareness of CO_2 emissions will have a significant impact on demand for motor vehicles, while car manufacturers increasingly consider CO_2 emission performance as a fundamental corporate challenge as well as a source of competitive advantage and opportunity to enhance their brand recognition (IBM, 2008).[9] At the same time, many governments have been moving towards the adoption of stricter CO_2 emission regulations, coupled with government incentives and subsidies to accelerate commercialization of low-CO_2 vehicle technologies (Deutsche Bank Research, 2009). Under strong pressure to reduce CO_2 emissions, the automotive industry has rapidly developed low-CO_2 technology while simultaneously pursuing cost-cutting efforts throughout the entire automotive value chain.

Traditional internal combustion engines, i.e., engines based on fossil fuels such as petrol and diesel,[10] have been refined together with other design and functional improvements. Alternative low-CO_2 fuels play an increasingly prominent role, while the adoption of full electric drive trains is seriously being considered by the automotive sector.[11] Technical options for the reduction of CO_2 emissions by both government and the private sector, including in developing countries in the region, have increased. However, the biggest challenges facing the development of new drive train technologies and use of alternative fuels are posed by the high investment costs associated with research, production and infrastructure development, which are likely to significantly increase prices of new cars and affect their rapid commercialization. This implies that CO_2 emission

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[9] For example, car manufacturers producing lower-CO_2 vehicles could see growth in sales and profits, while others who continue to depend on CO_2-intensive segments could see a fall in sales and profits (Sauer, 2005).

[10] Since there are only moderate differences in CO_2 emissions produced by conventional internal combustion engines and other emerging drive trains, such as electric motors (International Panel on Climate Change, 2007; and WBCSD, 2001), this paper does not cover different types of internal combustion engines separately, such as petrol and diesel. However, diesel engines create more polluted emissions, such as NOx and particulate matter, than equivalent petrol engines (Incerti, Walker and Purton, 2005). More stringent requirements for diesel vehicles, such as end-pipe devices like catalytic converters, have been recently observed (Energy Foundation, 2001).

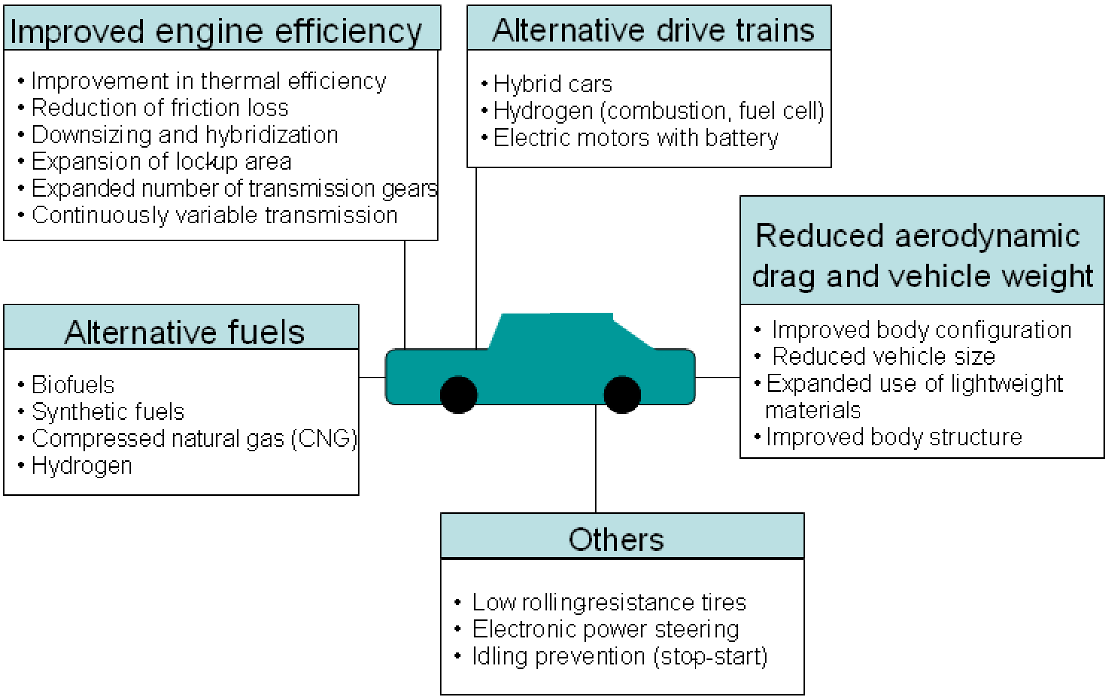
[11] In addition to small new entrants including Tesla, BYD and Coda Automotive, some major automakers, such as Ford, GM, Mitsubishi, Nissan and Renault, plan to introduce mass market battery electric vehicles before 2013 (PRNewswire, 2010).

abatement costs are still high in the automotive sector, and that further research and development of eco-friendly technologies are required, with government support.

Technology development will have a strong impact on energy efficiency and costs of drive trains. The opportunities and challenges for the development of low-CO_2 technologies in the next few decades are well recognized and documented (cf. European Automobile Manufacturers' Association, 2007; JAMA, 2008; and WBCSD, 2004). The focus has been on the development of low-CO_2 emission vehicles and/or alternative fuel vehicles often by combining various drive trains with low-CO_2 fuels. A number of different vehicles are currently under development, or have been marketed, as next-generation vehicles. Hybrid vehicles (are increasingly in use, and the first generation of plug-in hybrid vehicles has recently been introduced to the markets. Electric vehicles, fuel-cell vehicles and hydrogen vehicles are projected to be in widespread use in the long term (Zhang and Cooke, undated).

Technical options for the reduction of CO_2 emission from motor vehicles can be broadly grouped in five categories: (a) improvement of conventional engine efficiency; (b) use of alternative low-CO_2 fuels; (c) use of alternative drive trains; (d) improvement of aerodynamics and reduction of vehicle weight; and (e) others (figure 20).

Figure 20. Vehicle technologies for reducing CO_2 emissions



Sources: Based on European Federation for Transport and Environment, 2005, JAMA, 2009a, McKinsey & Company, 2008, Toyota, (2006, and Wansart, Walther and Spengler, undated.

Conventional engines, (both petrol and diesel) can be improved further to achieve higher fuel efficiency, thus lowering CO_2 emissions. Various technical options are still available for the automotive sector through the development and application of new technologies as well as the refinement of existing technologies. The technical options in this area, which could be implemented at relatively low cost within a short period, include:

(a) Improvements in thermal efficiency (e.g., direct injection);

(b) Reduction in friction loss (e.g., reduction of piston friction and low-viscosity lubricating oil);
(c) Refined gasoline and diesel combustion engines (e.g., downsizing and hybrids);
(d) Expansion of lock-up area;
(e) Expanded number of transmission gears;
(f) Continuously variable transmission.

Car manufacturers are expected to reduce the fuel consumption of conventional engines by a further 20 per cent to 25 per cent across all vehicle classes in the near future by applying these various options (Deutsche Bank Research, 2009). However, the reduction in CO_2 emissions from the improvement of conventional engines are not expected to offset rising CO_2 emissions resulting from rapid increase in vehicle use and travel distance.

Alternative fuels for low-CO_2 emissions, such as biofuels and compressed natural gas (CNG), have been researched, developed and marketed in past decades. They already play a major role around the world and their use is constantly rising. One notable example is Brazil's advanced usage of biofuels; 90 per cent of motor vehicles in Brazil are powered by flex-fuel engines consuming biofuels, which account for more than 17 per cent of the annually required vehicle fuels (Verband der Automobilindustrie, 2009; Rodrigues and Accarini, undated).

It is also possible for Asia-Pacific countries to increase their consumption of biofuels, such as ethanol or biodiesel, if they solve supply-side issues including conflicts with food production and availability of farmland. The competitiveness of biofuels compared with fossil fuels would also be strongly determined by the regulatory environment (e.g., fuel tax and blend levels), and by oil and gas prices. Second-generation biofuels, in which whole plants and, above all, crop waste can be converted into energy and/or fuel should have an even smaller CO_2 footprint than today's biofuels; they should also help to reduce conflicts over the use of farmland and food production.

One advantage of biofuels is that the existing infrastructure (e.g., the network of filling stations) can be used without the need for comprehensive retooling and expansion investments. CNG is also increasingly being used as a fuel for motor vehicles as shown by the number of gas-powered vehicles worldwide, which climbed from 1 million in 2000 to more than 9 million by 2008 (Deutsche Bank Research, 2009). CNG is widely promoted through government incentives (e.g., a lower petroleum tax rate) as it emits lower levels of CO_2 and other pollutants than petrol and diesel. Hydrogen has also been considered as an important vehicle fuel for the future. However, high research and development costs as well as the required infrastructure for hydrogen distribution are major obstacles to its commercialization and marketing. Thus, its use is expected to begin only after 2020 (McKinsey & Company, 2008).

To fully offset future additional CO_2 emissions from increased vehicle fleets and travel distance, the automotive sector must develop and market alternative drive trains. The internal combustion engine, which still dominates the automotive sector, is not an effective technology. Only 20 per cent or so of the energy derived from petrol or diesel is used to move the vehicle, while the remaining 80 per cent is wasted as heat. On the other hand, vehicles powered by electric motors can convert roughly 65 per cent of the energy drawn from the battery or fuel cell to vehicle movement. Thus, simply switching from internal combustion engines to electronic motors would sharply reduce energy demand and lower CO_2 emissions from vehicles (Earth Policy Institute, 2008).

Hydrogen fuel cell and electricity storage (e.g., lithium-ion batteries) are expected to be the main power generators for electric motors with low-CO_2 emissions in the long term, although the conventional internal combustion engine will continue to maintain its dominant position in vehicle drive trains in the short term (cf. Deutsche Bank Research, 2009).

Reduced aerodynamic drag and reduced vehicle weight through improved body configuration, reduced vehicle size and use of lightweight materials are also important in improving fuel economy and lowering CO_2 emissions. Finally, other modalities for reducing CO_2 emissions include the use of low rolling-resistance tyres and electronic power steering as well as improved driving behaviour (preventing stop-start).

Table 3 summarizes the present status of various alternative drive trains and fuel types as well as their combinations. It highlights the characteristics of each drive train and fuel combination in terms of CO_2 reduction potential, production and running costs, performance, required infrastructure, time of availability and barriers to effective market penetration.

Electric vehicles and fuel cell cars using renewable energy sources (e.g., biofuels,[12] solar energy and nuclear energy) have the highest potential for CO_2 emission reduction, but both technologies involve higher costs and longer development lead-times among the technological options. Battery-electric vehicles using renewable energy are regarded as zero CO_2 emission vehicles (Wansart, Walther and Spengler, undated). However, electric vehicles and fuel-cell cars cannot reduce CO_2 emissions by much if they still use fossil fuels as their main sources of energy. Although they produce no CO_2 emissions during their use, the manufacturing of batteries is energy- and fuel-intensive, and relies on electricity generated largely by fossil fuels. Many electric vehicles for the mass market were introduced in the late 2000s; however, their use is limited to special purposes (e.g., public fleets, community services and CO_2 awareness campaigns) mainly due to their high cost,[13] low performance (i.e., low running speed and limited travel distance) and low usability (i.e., long recharge time). In particular, electric vehicles require large high-capacity batteries for energy storage, which affect vehicle cost, weight and performance. The development of full performance electric vehicles, which are defined as fully capable of high-speed expressway driving, is expected. Fuel-cell electric vehicles with adequate performance could be developed by 2020, but successful commercialization depends on achieving massive cost reduction and creating an adequate hydrogen infrastructure (Walsh, 2009).

Governments, in close collaboration with the automotive sector, can also play an important role in this area by promoting and possibly sponsoring research and development of new vehicle technologies. Appropriate government policies could drive the development and availability of clean, affordable low-CO_2 drive trains and alternative fuels as well as necessary fuel and power supply infrastructure. Carefully targeted government incentives could be provided to promote the penetration of clean vehicle technologies in the market.

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[12] However, biofuels made from crops can only be considered truly renewable if their production is not threatening food and water supply or the environment, and if they are economically competitive with other fossil fuels. Further research is also necessary to develop more sustainable second-generation biofuels from waste material and biomass. Second-generation biofuels, such as cellulosic ethanol, "biomass to liquid" (BTL) and renewable diesel, may reduce CO_2 emissions by up to 90 per cent compared with conventional fossil fuels (OICA, undated).

[13] Note that recharge cost for electricity are lower than the costs associated with conventional fossil fuels (e.g., one-third of the fuel cost of an average petrol or diesel car) (Deutsche Bank Research, 2009).

Table 3. Drive train and fuel combinations, and their characteristics

	CO_2 reduction	Production costs	Running costs	Performance	Infrastructure requirements	Time of availability	Barriers
Hybrid	Moderate	Moderate	Low	Moderate	Not required	Available	
Plug-in hybrid	Moderate	High	Low	Moderate	Required	From 2010/11	Battery, charge station
Autogas/CNG	Moderate	Moderate	Low	Moderate	Required	Available	Storage
Biofuels	Moderate	Low	Low	High	Required	Available	Availability (biomass, land), competition with food
Second-generation biofuels	High	Low	Moderate	High	Required	Not before 2015	Technology, environmental impact, competition with usage of other sectors
Electric vehicles (electricity from fossil fuels)	Low	Very high	Very low	Low	Highly required	Available	Battery, charging station
Electric vehicles (electricity from renewable source)	Very high	Very high	Very low	Low	Highly required	Available	Battery, charging station
Hydrogen fuel cell (from fossil fuels)	Low	Very high	Moderate	High	Highly required	Not before 2020	Technology, stack, storage, durability
Hydrogen fuel cell (from renewable sources)	Very high	Very high	High	High	Highly required	Not before 2020	Technology, stack, storage, durability

Source: Adapted from Deutsche Bank Research, 2009, and International Panel on Climate Change, 2007.
Note: Schematic comparison with conventional engines (i.e., petrol and diesel).

4. Policy options for the development of the Asia-Pacific low-CO_2 automotive sector

This section draws on the findings of the previous sections, and presents various policy options for reducing CO_2 emissions and improving fuel efficiency in the automotive sector in Asia and the Pacific while ensuring the growth of the sector as well as its contribution to economic growth and development. This section also identifies areas for regional cooperation and the role of the private sector and public-private partnerships in ensuring sustainable trade and investment in the automotive sector in the region. After summarizing existing policies in Asia and the Pacific as well as other regions, five broad policy options are proposed: (a) vehicle taxation based on CO_2 emissions; (b) vehicle regulations, particularly fuel efficiency standards; (c) promotion of investment in fuel-efficient, low-CO_2 vehicles; (d) better traffic management and infrastructure; and (e) training and awareness enhancement.

A. CO_2 emission-related policies and regulations for the automotive sector

Policies aimed at reducing CO_2 emissions from the automotive sector include the regulation of vehicle CO_2 emissions and fuel standards, application of CO_2 and fuel taxes, enforcement of preferential sales and registration taxes for low-CO_2 vehicles, and government incentives for biofuels. Additional measures, such as road pricing and investing in public transportation infrastructure, can also to help reduce vehicle demand and, thus, lower CO_2 emissions. Some of those policies provide incentives to buyers to choose low fuel-consuming vehicles (Timilsina and Shrestha, 2009).[14] Overall, an increasing number of governments have differentiated vehicle-related policy instruments according to vehicles' fuel efficiency and/or CO_2 emissions, and taxing higher CO_2 emission cars more than lower emission cars.

Specific policy and regulatory options for reducing CO_2 emissions include the:

(a) Imposing fuel efficiency (or economy) standards;

(b) Diversification of alternative low-CO_2 fuels, including the development of infrastructure for the supply and distribution of different types of fuels and energy;

(c) Fuel taxes on conventional fossil fuels;

(d) Promotion of low-CO_2 emission technologies (improvements in traditional and hybridized internal combustion engines, fuel cell vehicles and electric vehicles);

(e) Changes in consumer choices and purchase decisions towards lower CO_2 emissions through fiscal instruments (e.g., CO_2-related taxation, such as fuel tax, and differentiated vehicle registration and purchase taxes);

(f) Improvement of traffic flow and reduction of wasteful congestion, for example, through upgrading of roads, urban planning, infrastructure development, effective facility (e.g., signal controlling system) and parking management;

(g) Reduction in vehicle travel demand (e.g., a reduction in the number and length of trips through proper land use, and the provision of low-CO_2 public transportation as an alternate transport mode[15] for adequate mobility options);

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[14] The promotion of low-CO2 vehicles, such as hybrids, through tax credits has also become a popular policy instrument.

[15] Developing countries in Asia and the Pacific may use more of their stimulus packages and the financing provided by international financial institutions for the development of more energy-efficient, lower CO_2 emission transport modes and infrastructure, improvement of public transportation and the use of greener vehicles. Those transport

(h) Enhancement of consumer CO_2 awareness to reduce fuel consumption and CO_2 emissions (e.g., education of drivers for eco-driving[16]).

The strategies being used to reduce vehicle CO_2 emissions fall within three broad groups: (a) economic and financial; (b) vehicle standards and traffic control; and (c) training, persuasive and information measures. Economic and financial strategies normally employ fiscal instruments, such as taxes, subsidies, grants and fees, to increase the costs of high-CO_2 emission vehicles at both the initial and operational stages, and encourage the shift towards lower CO_2 emission vehicles. For example, fuel taxes provide a broad incentive to improve fuel efficiency as they affect choices of vehicle, driving behaviour and annual mileage (European Federation for Transport and Environment, 2005).[17]

Strategies targeting vehicle standards and traffic control focus on technical regulations of vehicles' CO_2 emissions and transport mode management aimed at encouraging the production and use of more fuel-efficient cars. Such strategies also involve the restructuring of urban transport systems with the focus on improving access to rail and rapid bus transit with designated lanes, and making access for pedestrians and bicyclists a priority (Earth Policy Institute, 2008).

Strategies targeting training, persuasive and information measures are aimed at changing users' behaviour and, in particular, encouraging users to choose low-CO_2 emission transport modes or driving styles. CO_2 emission labelling schemes can be implemented to provide consumers with the necessary information to help them choose low-CO_2 emission cars. Tables 4, 5 and 6 summarize the policy instruments of these three strategies, with examples of their application in selected Asia-Pacific countries.

Table 4. Economic and financial strategies for lowering CO_2 emissions from the automotive sector

Acquisition tax	• Lower tax for smaller engine capacity (China). • Tax cuts for compact and hybrid cars and a subsidy for natural gas vehicles (Republic of Korea). • Auctioned vehicle permits (Singapore). • Tax and fee reductions or exemptions for new clean, fuel-efficient cars (Japan).
Excise tax	• Lower tax for compact cars and eco-cars, including hybrid, electric, fuel cell and alternative fuel vehicles (Thailand).
Annual circulation tax	• Annual vehicle attribute taxes and fees (European Union). • Annual fees for CO_2 and smog externalities (European Union). • Differentiated tax by vintage (Singapore, India and the European Union). • Emissions-tax deductions on cleaner cars, e.g., battery operated or alternative fuel vehicles (Republic of Korea, European Union and Japan). • Special tax for diesel-driven vehicles (Singapore).

modes may include, among others, rail and bus rapid transit systems, and integrated public and non-motorized transport.

[16] Fuel-conserving eco-driving has been shown to increase on-road vehicle fuel efficiency by between 6 per cent and 25 per cent in the short term (JAMA, 2008). See details of eco-driving at www.ecodrive.org.

[17] It might be argued that fuel taxes already serve the purpose of a CO_2 tax, although many of them have been implemented as a secured source of public funds.

Fuel tax	• Petrol/diesel tax (Singapore). • CO_2 tax (Sweden). • CO_2 tax according to engine size • 50 per cent or higher of crude oil base price (European Union and Japan). • Tax incentives to promote use of natural gas (Australia and Canada, European Union, Pakistan and the Russian Federation). • Urban gasoline tax (Canada). • Cross-subsidization of cleaner fuels, e.g., ethanol blending by petroleum tax through imposition of lower surcharge or excise duty exemption (India). • Fuel refund and subsidy for compact cars, trucks and taxis (Republic of Korea). • Lower biofuel tax (Thailand).
New vehicle incentives	• Clean-car rebates (Japan and United States). • "Gas guzzler" tax (United States). • Variable purchase tax with fuel consumption (Austria). • Incentives to promote natural gas vehicles (Australia, Malaysia, Pakistan, India, Islamic Republic of Iran, United Kingdom and United States). • Tax relief based on engine size, efficiency and CO_2 emission (European Union and Japan). • Early scrapping (China). • Rebate for new and green cars (Singapore). • Clean energy vehicles (Thailand).
Road fees	• Road pricing/high occupancy toll lanes (United States). • Congestion pricing (United Kingdom). • Electronic road pricing (Singapore). • Road and bridge fee (Viet Nam). • Low parking fees and toll cuts for compact cars (Republic of Korea).
Vehicle insurance	• Fines for lack of mandatory insurance (United Kingdom and United States). • Insurance-specific auto tax (France). • Pay-as-you-drive and pay-as-you pump insurance (United Kingdom and United States).
Fleet vehicle incentives	• Cost-effective, clean and fuel-efficient public fleets (Canada). • Incentives for clean, fuel-efficient company cars (United Kingdom). • Incentives for public transport companies (Malaysia).
Incentives for developing clean car technologies, alternative fuels	• Subsidies and grants for introducing clean and environmentally-efficient technologies (China and Japan). • Incentives for particular technologies and alternative fuels (European Union, Japan and Thailand). • Exemption of corporate income tax and import duties throughout the national value chains of eco-cars and renewable and alternative fuels (Thailand).

Congestion pricing	• Area licensing scheme, vehicle registration fees and annual circulation tax (Belgium, Chile, Norway and Singapore). • Toll pricing based on congestion charging (Republic of Korea and United Kingdom).

Sources: An and Sauer, 2004; Deutsche Bank Research, 2009; Hirota, 2010; International Panel on Climate Change, 2007; Tiasiri, 2010; UNEP, 2009; and WEF, 2009.

Table 5. Strategies for setting vehicle standards and improving traffic control

Fuel efficiency standards	Mandatory or voluntary numeric standards (Australia, Canada, China, Japan, Republic of Korea, Thailand, United States as well as Taiwan Province of China).
CO_2 emission standards	Mandatory and voluntary numeric standards (European Union and California).
Inspection and maintenance	Mandatory inspection at licence renewal (Japan and Thailand).
Speed control	Decreased transport speed and reduced congestion (e.g., installing speed limiter system).
Loading control	Optimized loading.
Logistic planning	Improved network planning through transportation projects (e.g., optimizing the networks of manufacturing locations, agriculture sector and logistics hubs).
Technology mandates	Sales requirement for zero emission vehicles or alternative fuel vehicles (California). Retrofit of old diesel engine vehicles (Thailand).
Traffic control measures	High occupancy vehicle lanes (in California as well as Thailand); banning SUVs (Paris).

Sources: An and Sauer, 2004; Hirota, 2010; UNEP, 2009; WEF, 2009; and Wichayarangsaridh, 2008.

Table 6. Strategies aimed at training, persuasive and information measures

Training	For road transport contractors and building operators on low-CO_2 operations. Eco-driving.
Mode sharing	Transfer freight from air and long-haul road transport to other low-CO_2 emission modes, such as ocean and rail.
Labelling	Labelling based on CO_2 performance.
New services	Encourage alternative transport services to deliver goods to home.
Behavioural changes	Car-free days (biking/walking/transit facilities) and carpool days. Telecommuting days.
Information dissemination	Clean car choice with public awareness of fuel consumption.
Weight minimization	Reduced weight and volume of packaging.

Sources: An and Sauer, 2004; Hirota, 2010; JAMA, 2008; UNEP, 2009; and WEF, 2009.

B. Vehicle-related taxation

One important policy option is to encourage people to purchase more fuel-efficient vehicles through economic and financial incentives, thus influencing the shift of carmakers' strategies towards the development of more fuel-efficient cars. This can be done through differentiated taxes on vehicles, according to their CO_2 emissions or fuel economy. Those CO_2-based taxes include acquisition and excise taxes, annual taxes, fuel and CO_2 taxes and others (see table 4 for more details). Those taxes have the clear advantage of giving credit to proactive car producers, an incentive that may prove essential to reducing specific CO_2 emissions to very low levels.

First, CO_2-based differentiated vehicle acquisition, excise and/or annual circulation taxes, which have been gaining popularity in Asia and the Pacific (e.g., China, Japan, the Republic of Korea and Thailand), can guide consumer demand further with regard to fuel-efficient vehicles. This policy option is particularly important in those countries where consumers prefer heavier and more powerful cars in order to discourage such purchases and make the market more acceptable of fuel efficiency considerations. CO_2-based annual taxes, such as a vintage tax and a special tax for diesel-engine cars, also discourage consumers from driving less fuel efficiency cars and encourage them to switch to more fuel efficiency cars.

To maximize their effectiveness, such taxes also need to be coherent with other incentives, differentiated according to the level of vehicle CO_2 emissions, such as fuel efficiency standards and labelling systems. Care must be taken to ensure that such taxes facilitate fleet changes to CO_2-efficient vehicles, and that they are applied in such a way as to avoid fragmentation of vehicle segmentations and different drive trains as well as fuel types that would increase costs and weaken their impact on CO_2 reduction. (For example, loopholes of taxations for large, powerful but profitable vehicles for carmakers need to be closed, so that consumers and carmakers can avoid such less fuel-efficient car segmentation). Governments also have a responsibility to minimize the costs associated with the imposition of taxes, for example, by keeping the differentiation of acquisition or excise taxes simple (and similar across regional markets) as well as by ensuring coherence with vehicle fuel-efficiency labelling systems. As many countries have moved to this policy option already, they could share their experiences and best practices at a regional forum to further improve their policies and regulations in this area.

Next, CO_2 taxes (or cap-and-trade systems[18] or other CO_2 pricing mechanisms such as fuel taxes on petrol and diesel), which have been implemented in European and especially Scandinavian, countries since the early 1990s, put a price on the release of CO_2 mainly from fossil fuel combustion systems (WTO, 2009). In so doing, CO_2 taxes have been regarded as having a great impact on consumer behaviour, particularly with regard to consumer purchasing decisions and travel demand, and, as a result, on the choice of technologies deployed by carmakers. For example, OECD (2008) reported that when countries increased their fuel taxes they had achieved significant improvements in fuel efficiency.

In section 2, subsection C, six factors were presented as the key drivers of CO_2 emissions from vehicles: (a) travel demand; (b) transport infrastructure; (c) transport modes; (d) fuel economy; (e) fuel CO_2 content; and (f) the way of driving (figure 16). Cutting vehicle CO_2 emissions requires a balanced approach to addressing all these factors; thus, policies aimed at

[18] Under cap-and-trade systems, CO2 emissions are capped, and permits to emit CO2 can be freely allocated and traded among CO2 producers through a market mechanism (WTO, 2009).

reducing the contribution of the auto sector to climate change must focus on how to change these six critical factors. However, a key challenge is that each factor is the product of decisions made by many actors, such as consumers, automakers, energy industry and policymakers (DeCicco and Fung, 2006). CO_2 taxes could provide a practical solution in this regard.

CO_2 emission taxes have been increasingly advocated as effective policy instruments that simultaneously address three of the six key CO_2 emission factors in the automotive sector, i.e., travel demand, fuel economy and fuel CO_2 content (cf. DeCicco and Fung, 2006; and Kopp, 2007).[19] A CO_2 tax allows efficient trade-offs among the three factors, resulting in effectively decreasing aggregate vehicle CO_2 emissions. Policies that only target vehicle fuel economy or fuel CO_2 content, by contrast, do not provide incentives for reducing vehicle use (Kopp, 2007). CO_2 taxes will decrease vehicle travel demand by increasing vehicle travel cost, while encouraging technological advance for higher fuel efficiency and a shift to increased use of low-CO_2 fuel. CO_2 taxes could be coupled with fuel efficiency standards, but they have to be mutually consistent; inconsistency between them could reduce their effectiveness to reduce CO_2 emissions and send unclear signals to carmakers.

However, a CO_2 tax might negatively affect trade and investment in the car-manufacturing developing countries of the Asia-Pacific region.[20] In emerging economies, such as China, India and the Russian Federation, most of the CO_2 emissions come from coal-fired power plants, which are a cheaper source of energy but are highly CO_2-ized, compared with power plants in industrialized countries, which also manufacture motor vehicles (see section 2, subsection A above). Although China, India and the Russian Federation do not, as yet, record large exports of cars – their car production is primarily for the domestic markets – exports are expected to grow as these countries compete on the basis of low costs. CO_2 taxes as well as subsidies for low-CO_2 car production in developed countries would affect their competitiveness. In any case, the implementation of CO_2 taxes as well as associated border tax adjustments and export subsidies, which account for CO_2 emissions attributable to imports and exports between nations under different regulations,[21] are controversial under the rules of the multilateral trading system (WTO, 2009).

As the assessment of the results of existing CO_2 taxes and equivalents is still in its early stage, more studies are required at the regional and global levels, especially for developing countries in the Asia-Pacific region. Such studies may specifically focus on existing and emerging regulations, trade exposures, energy structures and CO_2 emission intensities.

C. Fuel-efficiency standards

Fuel efficiency and CO_2 emission standards, including CO_2 emission labelling systems, have emerged as a particularly powerful tool to promote the reduction of CO_2 emissions from automobile use. American, European and Japanese, among other automobile manufacturers, have steadily increased the average fuel efficiency of new cars in compliance with relevant fuel efficiency standards. Table 7 summarises the fuel efficiency standards in economies around the world, including five Asia-Pacific economies, i.e., Australia, China, Japan, the Republic of Korea

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[19] CO_2 taxes are also expected to have an indirect impact on other factors (i.e., transport infrastructure, transport modes and way of driving) as they affect consumer choice and behaviour.

[20] On the other hand, differences among countries' CO_2 -related regulations could accelerate "CO_2 leakage" (i.e., automobile factories may relocate to countries with less costly CO_2 regulations or "CO_2 havens").

[21] Other measures may include trade bans and/or trade tariffs applied to nations that do not tax CO_2 emissions.

and Taiwan Province of China. It is noteworthy that among non-OECD developing countries in Asia and the Pacific, only China has so far enforced CO_2 emission standards.

Table 7. Fuel economy and CO2 emission standards around the world[22]

Country/ region	Standard	Measure	Structure	Targeted fleet	Test cycle*	Implementation
Australia	Fuel	l/100-km	Single standard	New	NEDC	Voluntary
Canada	GHG (CO_2, CH_4, N_2O, HFCs)	5.3 Mt reductio n	Vehicle class-based	In-use and new	CAFE	Voluntary
China	Fuel	l/100-km	Weight-based	New	NEDC	Mandatory
European Union	CO_2	g/km	Single standard	New	NEDC	Voluntary
Japan	Fuel	km/l	Weight-based	New	JC08	Mandatory
Republic of Korea	Fuel	km/l	Engine size-based	New	EPA City	Mandatory
Taiwan Province of China	Fuel	km/l	Engine size-based	New	CAFE	Mandatory
United States	Fuel	mpg	Single standard for cars and size-based standards for light trucks	New	CAFE	Mandatory
United States of America (California)	GHG (CO_2, CH_4, N_2O, HFCs)	g/mile	Vehicle class-based	New	CAFE	Mandatory

Source: International Council on Clean Transportation, 2009.
* See the annex for details.

The criteria applied to fuel efficiency standards vary depending on the country or region of implementation. First, the standards typically target one of three related but different objectives, i.e., fuel economy, fuel efficiency and CO_2 (and other greenhouse gas) emissions. Second, the standards use different test methods, such as test driving cycles (i.e., CAFE, JC08 and NEDC; see appendix for their details). Third, they are implemented on either a mandatory or a voluntary basis, although the global trend is shifting towards mandatory regulatory standards (e.g., the European Union's new mandatory regulation of 2008, and Canada's new vehicle emissions standards for 2011 and later model passenger cars and light trucks). Fourth, different safety regulations and compliance methods are enforced. As a result, it is difficult to compare the existing standards with total accuracy (IEA, 2009b). As many different fuel efficiency standards exist worldwide, the automotive sector has proposed the development of universal standards for the global market (Toyota, 2006; and OICA, undated).

[22] The Corporate Average Fuel Economy (CAFE) Act of the United States is the oldest GHG emission-related mandatory requirement in the world, which was in place in 1975 following the first oil crisis in order to improve oil supply security. The European Union imposed short- and long-term mandatory limits on CO_2 emissions in 2008 due to a failure of an earlier voluntary agreement on CO_2 emission targets. Japan introduced the first fuel economy requirement in the world for heavy trucks (Walsh, 2009). Regulating average CO_2 emissions from corporate car sales is another option, which is what the United States has done through its CAFE Act.

The different requirements of the various fuel efficiency standards among vehicle segments and/or weight-classes have become a critical issue for the effectiveness of the standards. Three types of requirements are widely used (European Federation for Transport and Environment, 2008). First, weight-based standards encourage the development of technologies for greater fuel efficiency while promoting product diversification. It may punish carmakers who produce lighter vehicles, one of the most important options for reducing CO_2 emissions and fuel consumption. Instead, such standards could lead to an increase in vehicle weight, and achieving the intended fuel efficiency could be more difficult.

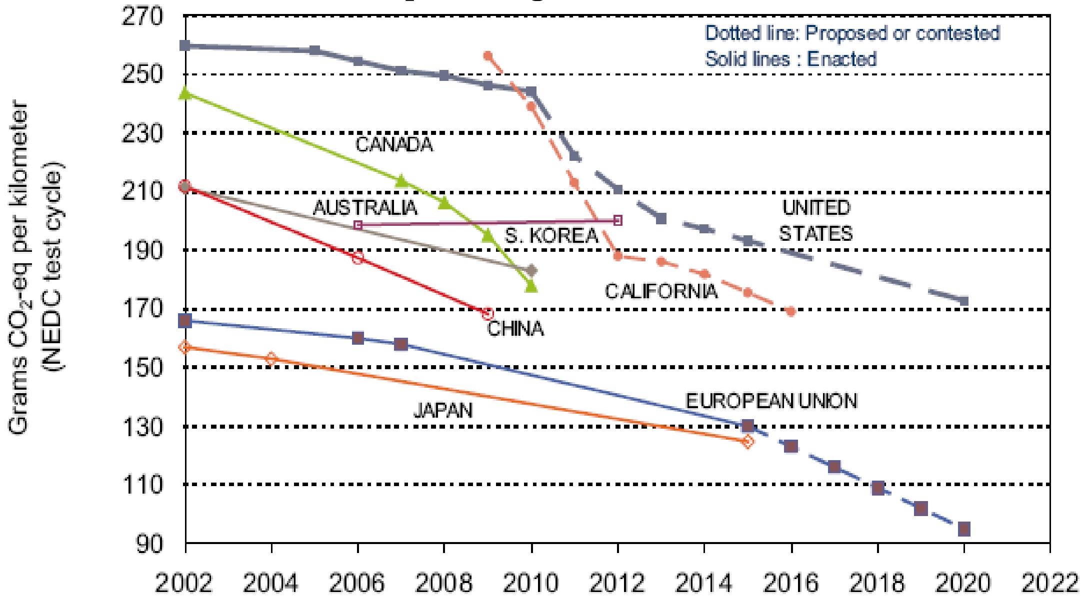
Second, footprint-based standards are based on track width multiplied by wheel base. Footprint-based standards leave more technological options open to carmakers for reducing CO_2 emissions and may not penalize weight reduction too much as a compliance option**.** However, their effectiveness may be smaller if carmakers move to high-profit large size vehicle segments, which carry heavier weights and thus less fuel economy.

Third, flat standards, not differentiated for vehicle weight or footprint, offer direct guarantees for achieving CO_2 emission targets and encourage greater fuel efficiency overall, regardless of vehicle weight and size. In any case, the achievement of CO_2 reduction targets must be guaranteed by correcting for unforeseen increases in average vehicle weight or footprint. However, such targets pose far greater compliance challenges for large-car manufacturers than for small-car manufacturers.

The standards currently in place cover a relatively short period, with none extending beyond 2020. Such short-term standards would leave increasing regulatory uncertainty for carmakers working with long development and investment cycles, which are required for the commercialization of new technologies. Fuel economy and CO_2 gas emissions standards create both financial risks and opportunities for carmakers. Overall, the automotive sector is under pressure to produce low-CO_2 vehicles in conformity with increasingly stringent regulations. Therefore, fuel economy will become a major driver in the financial performance of carmakers in the next decades (Sauer, 2005).

Figure 21 shows that the trends in CO_2 emissions of new passenger cars are in selected major auto producing countries, including selected countries in Asia and the Pacific, i.e., Australia, China, Japan and the Republic of Korea. Reducing CO_2 emissions are in line with the development of more stringent fuel economy and CO_2 emission standards in the world (table 7). The European Union and Japan have implemented the most stringent fuel efficiency standards. While most countries covered in figure 21 have recently experienced CO_2 emission reductions from passenger cars, the Republic of Korea has had (and expected) a flat level of CO_2 emissions.

Figure 21. Actual and projected CO2 emissions for new passenger vehicles, by major auto-producing countries, 2002-2020



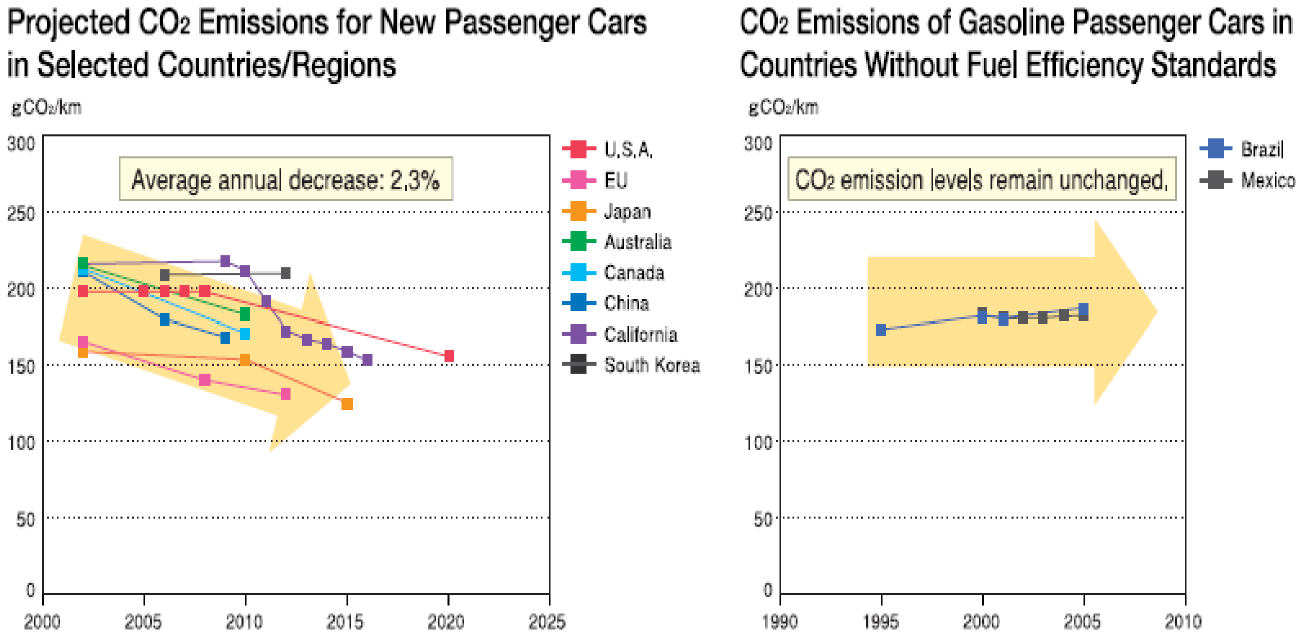
Source: International Council on Clean Transportation, 2009.[23]

If the various standards are enforced as planned, the average reduction rate of CO_2 emissions from new passenger cars will be 2.3 per cent annually (JAMA, 2008). In contrast, it is estimated that CO_2 emissions from petrol-fuelled passenger cars have not decreased in countries where fuel efficiency standards have yet to be introduced, e.g., Brazil and Mexico (figure 22). However, the worldwide growth of vehicle population and vehicle kilometres travelled, especially in developing countries in the Asia-Pacific region as reviewed in section 1, coupled with the trend of increasing vehicle weights could offset the CO_2 reductions made to date by fuel efficiency standards.

The extent of regulation of truck fuel efficiency and CO_2 emissions varies, depending on the country or region of implementation. For example, the United States applies its flat standards (i.e., CAFE) to a single category, i.e., light-duty trucks. Japan, however, has already introduced fuel efficiency standards for trucks of all weight categories.

[23] The International Council on Clean Transportation approach converts each country's test numbers to a common (NEDC) test cycle, based on modelling estimates. (For detailed methodology refer to the appendix in International Council on Clean Transportation, 2009).

Figure 22. Projected CO2 emissions for new passenger cars in selected countries/regions with and without fuel efficiency standards



Source: JAMA, (2008.

Individual countries (those that are manufacturing and those that are importing motor vehicles) must adopt vehicle fuel efficiency standards that are suitable to national (and perhaps regional and global) circumstances, and are integrated into the development strategies of their national automotive sector. Following the global trend, it would also be important to review, renew and tighten these standards over the years in order to keep on improving fuel economy. Most developing countries in Asia and the Pacific, however, have yet to develop fuel efficiency standards. As an increasing number of new vehicles will be sold in developing countries, particularly in the Asia and the Pacific region, during the coming decades it will be important for such countries to establish their own fuel economy regulatory systems.[24]

Standardizing international (or regional) regulations for CO_2 emissions and fuel economy is recommended. In particular, the establishment of global fuel efficiency standards, including a universal test-driving method and labelling schemes, would certainly have merit. Many countries, although less so in the Asia-Pacific region, have already established their own fuel efficiency standards and labelling systems, which must be linked to a uniform test cycle procedure to provide buyers (and carmakers)with a more realistic information on vehicle fuel consumption and related CO_2 emissions. However, fuel efficiency standards and labelling schemes differ significantly among individual countries (cf. CAFE, JC08, NEDC). Harmonization of vehicle standards and labelling schemes is desirable in order to provide consistent signals for buyers[25] as well as carmakers concerning product development and marketing across increasingly globalized car markets, and to facilitate trade and investment in the automotive sector. This will support

[24] There is an argument that stringent fuel efficiency standards raise costs of motor vehicles, which would harm carmakers and consumers alike (OICA, undated). However, this is not likely to happen as customers spend less on fuel and more on vehicles. Instead, the oil industry will be more affected.

[25] Buyers generally do not consider the entire fuel cost over the life of a vehicle. It is not fair to assume that they have adequate information on the life-cycle CO_2 emissions of the vehicle (e.g., well-to-wheels-to-waste CO_2 emissions). Thus, it is crucial to provide buyers with such information to encourage them to choose low- CO_2 vehicles, which would lead to further development of low-CO_2 technologies by carmakers.

decisions to buy low-CO_2 vehicles and maximize the overall effectiveness of regulations for CO_2 reduction. However, for those countries that already have fuel efficiency policies, increasing alignment with other countries' policies (and establish uniform standards) will only occur over time, as policies will have to be renewed and adjusted. For countries and regions where policymaking is just beginning, such alignment may possibly happen more quickly. In this regard, as many Asia-Pacific economies have not yet developed fuel efficiency regulations and labelling systems, this would be a good opportunity for the establishment of (sub)region-wide vehicle standards and labelling schemes, supported and moderated by international (or regional) agencies. Such region-wide standards could be more desirable as their adoption by automakers would be less costly than the adoption of various national schemes. At the same time, they would encourage intraregional investments for the development of advanced vehicles.

Finally, various developing countries in the region import a large number of second- and third-hand vehicles from neighbouring vehicle-producing countries (Singh and Kher, 2004). Such older vehicles typically have low fuel efficiency and thus produce higher CO_2 emissions than new vehicles. In this connection, a number of countries such as India, Indonesia, Malaysia, Singapore and Thailand have used regulations or incentives, such as emission inspection, importer's registration systems and differentiated tariffs, to promote fuel efficiency of imported second-hand vehicles and reduce the number of high-CO_2 emission vehicles in circulation. It is also recommended that such approaches be continued or strengthened while implementing effective recycling and waste management for older vehicles. This issue may be also addressed through a regional approach involving both vehicle exporting and importing countries.

D. Promoting investment in the development of fuel-efficient vehicles and alternative biofuels

Investment in designing and manufacturing CO_2-efficient vehicles (and associated technologies) and producing low-CO_2 fuels should be promoted through financial (or economic) incentives and/or regulations. The shift towards smaller (and light-weight) alternative drive train vehicles is crucial to ensuring a sustainable automotive industry in the future.

Such a shift could be realized by using lighter materials and compromising performance. Downsizing the vehicle body, engine and drive train makes the vehicle lighter, while carmakers must change their strategic focus from big, high-performing vehicles (e.g., multi-purpose vehicles and sports utility vehicles) to small, CO_2-efficient vehicles.[26] Improvements in traditional and hybridized internal combustion engine technology can deliver large reductions in CO_2 emissions in the short to medium term. The use of low-CO_2 fuels, such as sustainable biofuels with full life-cycle CO_2 savings, can also make a quick contribution to mitigation of CO_2 emissions. In particular, electrification of drive trains could play an increasingly important role over the longer term; however, issues related to battery costs, travel range and energy distribution will need to be addressed.[27] As it typically takes 15 to 20 years to replace the entire car fleet of a country, it might be a good idea to start the development of alternative fuel-efficient vehicles as early as possible, subject to the availability of advanced technologies in developing countries of the region, which is admittedly a problem for some.

[26] Such a change may have an impact on short-term corporate performance as big, high-performing cars have contributed to considerable profits in the automotive industry.
[27] The level of CO_2 emissions of electric vehicles depends on the CO_2 intensity of electricity generation. In those cases where coal-intensive electricity production dominates, which is the case in many developing countries in the Asia-Pacific region, electric vehicles may not reduce o-erall CO_2 emissions.

However, growing domestic markets for fuel-efficient cars could benefit those carmakers in Asia and the Pacific with an interest in international markets. For example, strong policy measures aimed at making vehicle fleets increasingly more fuel-efficient are being implemented in China, India, Japan, the Republic of Korea and Thailand (see table 4). Having a strong position in a growing low-CO_2 vehicle segment is likely to become a strategic and competitive advantage for many carmakers seeking to penetrate international markets. Governments and the automotive industry need to work together to ensure the adoption of effective regulatory standards and incentives for CO_2 emission reduction while meeting market demand and consumer preferences at the national, regional and global levels.

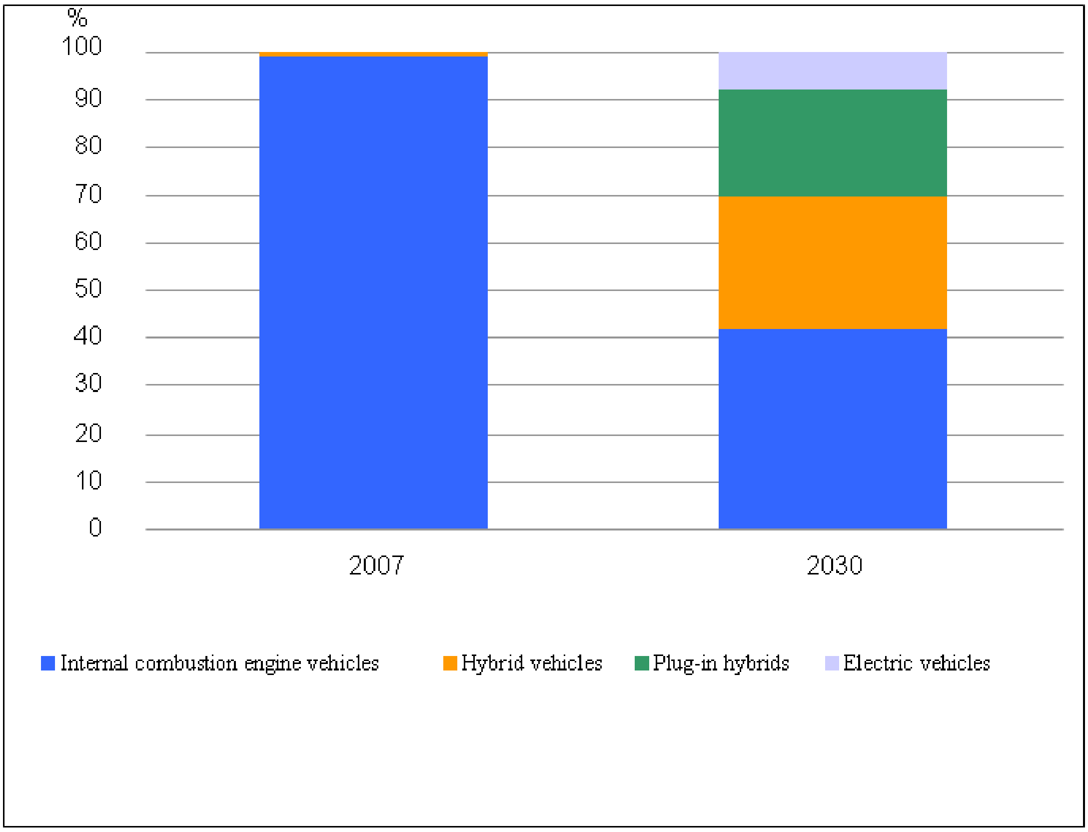
There has been a strong regulatory movement to promote the use of alternative low-CO_2 fuels in the world. A number of countries in Asia and the Pacific have also moved to develop lower-CO_2 fuels for vehicles such as biofuels and CNG (e.g., Thailand). However, region-wide alternative fuel standards have yet to be developed in Asia and the Pacific. On the other hand, California recently proposed CO_2-based fuel requirements, and the European Union is pursuing low-CO_2 fuel standards (LCFS). The goal of LCFS is to promote investment in, and use of low-CO_2 fuels (e.g., sustainable ethanol and biodiesel, CNG and renewable electric/hydrogen) as well as to reduce demand for high-CO_2 fuel sources (e.g., tar sands, shale oil and coal to liquids).

The current United States Renewable Fuels Standard (RFS) has taken a step towards LCFS by requiring life-cycle CO_2 emission standards for three categories of biofuels: (a) baseline renewable biofuels (20 per cent below petroleum in terms of CO_2 emissions), advanced biofuels (50 per cent improvement) and cellulosic biofuels (60 per cent improvement). The RFS, however, only applies to biofuels and thus does not dampen demand for conventional high-CO_2 fuels (Walsh, 2009). Following this trend, the Asia-Pacific countries may consider developing region-wide alternative fuel standards for vehicles, with a special emphasis on biofuels. Such regional standards would provide a clear signal to consumers while making automakers adopt less costly alternative fuels as well as facilitating their strategic shift to advanced technologies, including flex drive trains. In this sense, the standards can also provide a platform to facilitate interregional investments in the production of alternative fuels.

In order to ensure that low-CO_2 fuels actually provide global benefits, a full life-cycle analysis that includes direct and indirect land-use effects is needed, particularly for the development of biofuels. When such factors are taken into account, the development of low-CO_2 fuels that actually achieve significant benefits becomes a very difficult proposition. Various Asia-Pacific countries may also take steps to conduct life-cycle analyses on biofuel production within the region and share the results of the analyses for the production of quality biofuels in the region.

IEA (2009c) projects that if the CO_2 intensity of the global car fleet is cut by half over the next two decades through coordinated action and substantial investment in the development of advanced fuel-efficient vehicles, a dramatic shift in car sales will occur in the global vehicle market as by 2030 conventional internal combustion engines will only represent roughly 40 per cent of sales, a substantial drop from their nearly 100 per cent market share in 2007. Hybrid cars are expected to take up 30 per cent of sales and plug-in hybrids and electric vehicles account for the remaining 30 per cent (figure 23). It is estimated that an additional $4,750 billion needs to be invested globally in the development of advanced vehicles over the period of 2010-2030. Over 70 per cent of this investment ($3,350 billion) is supposed to be made to build more efficient passenger cars. Another $ 650 billion in investment will also be required for fuel-efficient heavy trucks and buses (IEA, 2009c).

Figure 23. Share of global passenger vehicle sales by drive train



Source: IEA, 2009c; and Stevenson, 2010.

Although it remains an issue how countries can meet such massive investment requirements, the move towards "greener" cars surely creates substantial business opportunities for automakers, and their parts and components suppliers, including those in the Asia-Pacific region (Stevenson, 2010). It will also provide significant challenges to the automotive sector in developing countries in Asia and the Pacific, where the capability and capacity of technology development is still constrained by limited financial and human resources. A coordinated policy framework as well as close cooperation with automakers and their suppliers at the regional level is desirable for developing and marketing advanced vehicles. Government policy and financial support would be particularly useful in the fields of research and development and human resources development. Boxes 2 and 3 take a closer look at the programmes implemented by China and Thailand.

Box 1. Thailand's eco-car programme

Since the mid-2000s, Thailand has been aggressively promoting investment in the development of fuel-efficient passenger vehicles under its eco-car programme. The programme is designed to attract major carmakers to relocate their production facilities for technologically advanced cars (e.g., hybrids, flex fuel, electric and fuel-cell cars) to Thailand. Thailand also aims to strengthen its automotive supply chains by attracting associated investment in eco-car production from automotive parts and components suppliers. This policy initiative is in line with Thailand's strategy for fostering its automotive sector's niche export market in addition to its traditional stronghold in the global pick-up truck segment (Abe, 2009). For this purpose, the programme has provided tax incentives to carmakers and consumers, including the exemption of corporate income tax and import duties for materials/parts and machinery as well as differential excise taxes based on different power trains (Tiasiri, 2010).

The eco-car programme has already secured commitments from six carmakers (i.e., Honda, Mitsubishi, Nissan, Suzuki, Tata and Toyota) for an expected total capital investment of more than US$ 2 billion for the annual production of more than 650,000 units of compact size fuel-efficient cars, with 60 per cent of them projected for export. The programme is expected to create 11,000 new jobs within Thailand. In the next step, Thailand is planning to overhaul the current excise tax structure to improve consumer incentives for eco-cars (*Bangkok Post*, 2010).

Box 2. China's massive electric and hybrid vehicle investment plan

The Government of China aims to become the global leader in electric and hybrid vehicles, and plans to produce more than 1 million electric and hybrid vehicles for the world's biggest and fastest-growing auto market in the next few years. The Government realizes that the competitiveness and sustainable development of the automotive industry lie in the successful development of fuel-efficient vehicles. Sixteen government-selected large state-owned companies agreed to form an alliance to carry out research and development, and to create standards for electric and hybrid vehicles, which will require active technology exchange within China's auto industry. The alliance comprises oil producers, power companies and military and aviation companies as well as two of the largest carmakers, FAW Group and Dongfeng Auto.

China plans to invest nearly US$ 15 billion in the venture, which would make it one of the world's largest investments, for developing vehicles that are more energy efficient (Barboza, 2010; and Hong and Mu, 2010). China's large reserves of rare earth minerals, which account for one third of the world's total and are critical inputs for the manufacturing of electric and hybrid vehicles (particularly those with electric motors), will be an advantage in implementing this strategy (Xinhua News Agency, 2010).

Technology development for affordable new drive trains, including low-cost, high-performing batteries, would be a major challenge to China's success in electric and hybrid vehicles. An incentive structure, such as tax breaks, subsidies and fuel tax, and supporting infrastructure development including electricity recharging stations, must also be addressed properly and quickly (McKinsey & Company, 2008). However, the lack of proper recycling and waste management for batteries as well as the domination of coal in energy generation in China may undermine the effectiveness of the strategic investment in low-CO_2 emission vehicles aimed at reducing overall carbon emissions in the country.

E. Better traffic management and infrastructure

Better traffic management and infrastructure have the potential to lead to significant reductions in CO_2 emission from motor vehicles through reduced congestion, discouragement of excessive speed and reduction of travel distance as well as vehicle demand. Mobility demand management, land-use planning and promotion of low-CO_2 public transport can all help to reduce CO_2 emissions. Freeing capacity through traffic management could lead to additional traffic in many circumstances, but even when overall travel increases, emissions may still be lower than previously if vehicles can efficiently travel at their optimal speed.

Developing countries in Asia and the Pacific, where rapid urbanization is progressing with lagging transport infrastructure, are encouraged to invest more in the upgrading of roads and the development of energy-efficient public transportation, e.g., rail and bus rapid transit systems. Governments, with support from international financial institutions, can also target investment in well-planned, low-CO_2 transport infrastructure that meets the needs of people. Upgraded road infrastructure will not only allow smoother traffic flow, thus saving fuel and, in turn, lead to lower CO_2 emissions; it will also reduce consumer demand for heavier vehicles, such as SUVs, which emit more CO_2 than light passenger cars. The development of public transportation together with appropriate urban planning will serve to create lower dependence on motor vehicles, reduce vehicle demand and support the increased use of public transport systems, particularly in developing countries in the region. Sharing experiences and best practices among those countries could also enhance the effectiveness of their actions in traffic management and transport infrastructure development.

F. Training and awareness

Behavioural changes can also lead to a reduction in total driving time through better planning of travel routes, the use of alternative modes of transport, car pooling, taking better care of fuel consumption while driving and regularly checking tyre pressures. Such behavioural changes can be achieved at less cost as well as quickly if appropriate training and awareness activities are implemented.

For example, training private and professional drivers in eco-driving, which can be implemented quickly at relatively low cost, can reduce CO_2 emissions by between 5 per cent and 25 per cent (JAMA, 2008). Given the high cost effectiveness of fuel-saving, eco-driving should be encouraged among drivers through training and information dissemination. In this regard, national awareness campaigns informing drivers of the financial costs of their driving styles would be useful. Such campaigns can be carried out through various communication modalities, including mass media and the Internet.

As mentioned above, consumer preferences for fuel-efficient vehicles would force automakers to change corporate strategies to the production of compact, light-weight vehicles as well as the development of low-CO_2 technologies. In this regard, a public awareness campaign for consumers on vehicle CO_2 emissions would be effective in forcing a demand-driven mitigation of CO_2 emissions from the automotive sector. However, cooperation from automakers would be vital for the campaign's success.

5. Conclusion: An integrated approach for Asia and the Pacific

As discussed above, several policy and technical options are available to governments and automakers (and their suppliers) within Asia and the Pacific, where the rapid development of the automotive sector is expected, for mitigating the level of vehicle CO_2 emissions in the next few decades. Various factors and players, however, are also driving CO_2 emissions from vehicles in the region, leaving complicated coordinating tasks for policymakers. At the same time, the implementation and development of most CO_2 emission-reduction initiatives and technologies will not be cost effective without some combination of support to facilitate the sector's investments in the reduction of vehicle CO_2 emissions. Such mechanisms should include economic incentives and regulatory regime improvements, possibly covering taxation, subsidies, industrial standards, vehicle regulations and transport infrastructure, while additional interventions may be necessary to soften the impact of such actions, such as behavioural changes and demand management, working primarily with consumers.

In order to address all the critical factors associated with cutting vehicle CO_2 emissions with the involvement of all key stakeholders, a region-wide approach will be necessary. In this context, an integrated policy approach for Asia and the Pacific, containing various measures with priority given to investment in energy efficient and low-CO_2 emission vehicles, is needed to meet short- and long-term economic and sustainability targets of the region. The benefits associated with most of the policy and technical options could be increased if the various available policy instruments were used in such a comprehensive integrated region-wide approach; this would reduce the implementation costs of such options at the regional level.

The integrated approach for the region should set long-term targets for CO_2 emission reductions, while implementing various policy measures that would reduce uncertainty and risk in the automotive sector and give automakers financial incentives to invest in new technologies. For example, introducing fuel-efficiency standards accompanied by appropriate fuel (or CO_2) taxes as well as subsides for research and development would encourage the adoption of advanced technologies in the sector, and result in substantial reductions of CO_2 emissions. Measures for encouraging behavioural change, together with demand management measures, would also be effective.

In this connection, it is strongly recommended that governments in the region, in cooperation with the automotive sector, urgently take the following actions:

(a) Develop guidelines for coordinated CO_2 related taxation;

(b) Establish regional fuel efficiency (or economy) standards, including alternative fuel standards.

Those two initiatives are most critical with regard to providing a foreseeable business environment for the automotive sector while avoiding financial incentives to a specific technology. That would put all technological options on an equal footing, allowing the sector to gain adequate time to facilitate their investment decisions in the development of various types of fuel-efficient vehicles in the Asia-Pacific region. Another important short-term measure could be to encourage governments and the automotive sector to share knowledge and best practices at the regional level.

Annex

Major fuel-economy test cycles

Name	Country	Description	Vehicle and engine type
JC08	Japan	JC08 is Japan's new official fuel-economy test cycle for new cars, expressed in kilometres per litre (km/l) for 2015, replacing the conventional "10.15 mode". JC08, which aims to cover real-world driving conditions, such as idling, acceleration, steady running and deceleration, and simulate typical urban and/or expressway driving patterns, is significantly longer and more rigorous than the 10.15 mode. It targets a 23.5 per cent improvement over the 2004 industry average, which stood at 13.6 km/l (JAMA, 2009b).	Passenger cars and light trucks and buses with petrol and diesel engines
NEDC	European Union	The New European Driving Cycle (NEDC), also referred to as the Motor Vehicle Emissions Group cycle, is European Union's fuel-economy test cycle consisting of four repeated conventional ECE-15 driving cycles and an extra-urban driving cycle. NEDC is supposed to represent the typical usage of a car in Europe and is used, among other things, to assess the emission levels of car engines expressing in grams per kilometre (DieselNet, undated).	Passenger cars
CAFE (including United States EPA city and highway tests)	United States of America	Corporate Average Fuel Economy (CAFE requires two different driving test cycles, which were developed by the United States Environmental Protection Agency, i.e., city and highway tests. The tests are conducted in controlled laboratory conditions (United States Environmental Protection Agency, 2004).	Passenger cars and light trucks

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