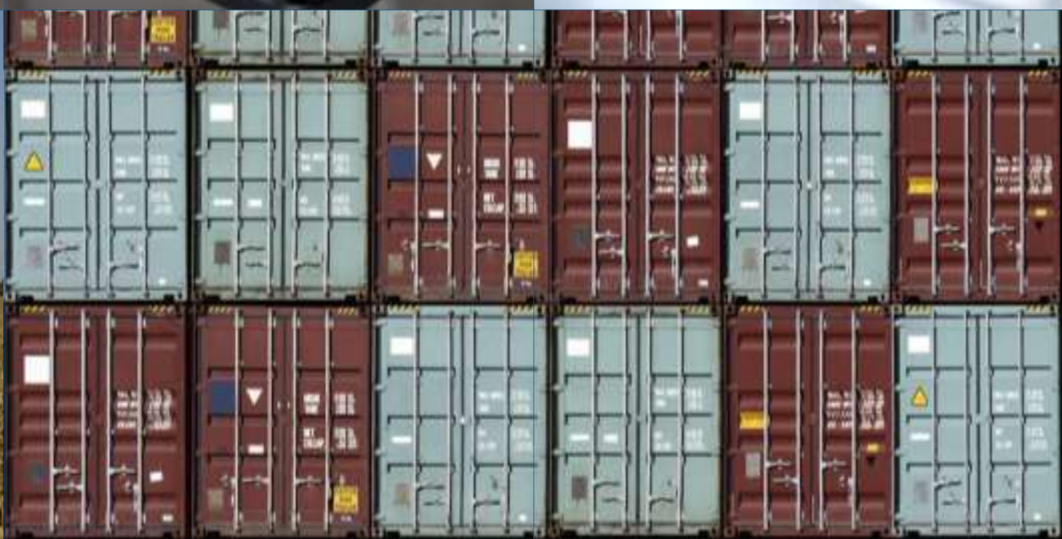
WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

Global Transport Scenarios 2050

World Energy Council

Project Partners
IBM Corporation
Paul Scherrer Institute



Global Transport Scenarios 2050

Officers of the World Energy Council

Global Transport Scenarios 2050
World Energy Council

Published 2011 by:

World Energy Council
Regency House 1-4 Warwick Street
London W1B 5LT United Kingdom

ISBN: 978-0-946121-14-4

Knowledge Network Members

Walter Böhme, Austria
Pietro Erber, Brazil
Renata Szczerbacki, Brazil
Lyudmil Kostadinov, Bulgaria
Terry Kimmel, Canada
Karim Kassam, Canada
Lesme Corredor Martinez, Colombia
José Maboya Nzalingo, Congo (DR)
Hans Larsen, Denmark
Georges Bouchard, France
Igor Czerny, France
Alain Le Duigou France
Pierre Sigonney, France
Alain Bucaille, France
Jean Eudes Moncomble, France
Simon Vinot, France
Enno Harks, Germany
Matthias Kirner, Germany
Kerstin Mayr, Germany
Alexander Stöhr, Germany
Christian Hahn, Germany
Ved Mitra, India
Anil Bakshi, India
Philip Thomas, India
Prakash Sharma, India
Antonio De Bellis, Italy
Davide Moroni, Italy
Andrea Zara, Italy
Federico Caleno, Italy
Kaoru Horie, Japan
Junhaeng Jo, Korea (Republic)
Rodolfo Lacy, Mexico
Pinehas Mutota , Namibia
Barry Blackett, New Zealand
Eli Bala, Nigeria
Mohammed Bello, Nigeria
Gabriela Prata Dias, Portugal
Alexandru Sandulescu, Romania
Ionut Purica, Romania
Alison von Ketelhodt, South Africa
Heloise Nel, South Africa
Jaime Gutiérrez, Spain
Almudena Rosas, Spain
Gunnar Bengtsson, Sweden
Jochen Kreusel, Switzerland
Abdelhamid Khalfallah, Tunisia
Sarper Saragöglu, Turkey
Martin Haigh, United Kingdom
Helen El-Mallakh, United States

Project Partner – Paul Scherrer Institute

Philipp Dietrich, Switzerland
Hal Turton, Switzerland
Martin Densing, Switzerland

Project Partner – IBM Corporation

Irina Bychkova, United Kingdom
Clay Luthy, United States
Sundar Iyer, United Kingdom
Steve Edwards, United Kingdom
Michael Valocchi, United States

Project Team

Christoph Frei, WEC, Secretary General
Karl Rose, WEC, Director Policy and Scenarios
Ayed Al-Qahtani, WEC, Senior Project Manager
Brian Statham, South Africa
Suduk Kim, Korea (Republic)

Content

Executive Summary

Over the next four decades, the global transportation sector will face unprecedented challenges related to demographics, urbanization, pressure to minimize and dislocate emissions outside urban centres, congestion of aging transport infrastructure and growth in fuel demand. These challenges will all be compounded by uncertainties emerging from government intervention and regulation. Regional and global cooperation, unstable global economic situations, and potential technological breakthroughs will all have a significant impact. In light of these challenges and the levels of uncertainty, the World Energy Council (WEC) decided to re-examine the future of the transport and mobility sector by building Global Transport Scenarios to 2050. These scenarios will describe potential developments in transport fuels, technologies, and mobility systems over the course of the next forty years. Undoubtedly, the evolution of the transport world between 2010 and 2050 will offer many challenges, the biggest of which is providing sustainable transport for the seven to nine billion people at the lowest social cost possible. These scenarios show that government policies will play a critical role in determining the most likely pathway into the future.

The World Energy Council believes that constructive dialogue between national and local policy makers, manufacturers, consumers and producers will be essential if we are to meet these challenges. Only with discovery, promotion and development of new energy resources, matched to innovation and improvements in current technologies, catalysed by optimally formulated policies can we hope to ensure a more sustainable transport future for current and future generations.

Now is the time for strong leadership at both government and enterprise levels if the transport sector is to make a positive contribution towards the well-being of future generations.

Regional inputs on transport policies, existing and potential developments in both fuels and technologies, in addition to major driving forces and critical uncertainties were all examined and combined into two distinct transport scenarios "Freeway" and "Tollway." The main difference between these two scenarios is the degree and style of government intervention in regulating future transport markets.

- The **"Freeway"** scenario envisages a world where pure market forces prevail to create a climate for open global competition.

- The **"Tollway"** scenario describes a more regulated world where governments decide to intervene in markets to promote technology solutions and infrastructure development that put common interests at the forefront.

The Freeway and Tollway scenarios describe the extreme ends of the potential futures envelope. The reality will inevitably be between these two scenarios with regional differences playing a major role.

In quantifying these two scenarios, we noted that by 2050:

- **Total fuel demand** in all transport modes will increase by 30% (Tollway) to 82% (Freeway) above the 2010 levels. The growth in fuel demand will be driven mainly by trucks, buses, trains, ships, and airplanes.

- Transport sector **fuel mix** will still depend heavily on gasoline, diesel, fuel oil and jet fuel, as they all will still constitute the bulk of transport market fuels with 80% (Tollway) to 88% (Freeway) in 2050.
- Demand for these **major fuels** will increase by 10% (Tollway) to 68% (Freeway) over the scenario period.
- Demand for **diesel and fuel oil** will grow by 46% (Tollway) to 200% (Freeway).
- Demand for **jet fuel** will grow by 200% (Tollway) to 300% (Freeway).
- Demand for **gasoline** is expected to drop by 16% (Freeway) to 63% (Tollway).

Biofuels will also help to satisfy the demand for transport fuel as their use will increase almost four fold in both scenarios. **Other fuels** including electricity, hydrogen, and natural gas will increase six to seven fold.

The additional transport fuel demand will come from the developing countries (especially China and India) where demand will grow by 200% (Tollway) to 300% (Freeway). In contrast, the transport fuel demand for the developed countries will drop by up to 20% (Tollway). The demand of the developing countries is expected to surpass that of the developed ones by the year 2025, if not earlier.

- The **total number of cars** in the world is also expected to increase 2.2 times (Tollway) to 2.6 times (Freeway), mainly in the developing world, where the number of cars will increase by 430% (Tollway) to 557% (Freeway) while the developed countries will see an increase of only 36% (Tollway) to 41% (Freeway).
- At the end of the scenario period (2050) we expect conventional gasoline and diesel internal combustion engines (ICEs) to have a **market share** between 26% (Tollway) and 78% (Freeway). Other drive-train technologies will make up the rest with liquid hybrid, plug-ins, and electric vehicles leading in Tollway, while liquid hybrids, plug-ins and gas vehicles lead in Freeway.

The scenarios also show significant regional differences, with shale gas being a driver for natural gas fuelled transport in North America, biofuels with a continued high contribution in Latin America, and electric mobility having a particularly strong push in Asia/China where the growth of megacities is most dramatic.

In 2010, the CO_2 emissions from the transport sector were about 23% of global CO_2 emission levels and emissions from cars were about 41% of total transport emissions. With the higher levels of transport demand, and depending on the fuel mix:

- The **total CO_2 emissions** from the transportation sector is expected to increase between 16% (Tollway) and 79% (Freeway), depending mainly on the degree of the government intervention and success in advancing low carbon fuel systems.

6

With this picture of the transport sector in 2050, and in light of the major drivers, WEC believes that the global transport sector can overcome the many challenges of meeting the global transport demand in the context of the Energy Trilemma. The biggest challenge will be to provide sustainable transport for the seven to nine billion people with the minimum possible congestion, pollution, and noise generated by additional traffic and freight. Understanding the dynamics and magnitude of these likely future developments can offer consumers, entrepreneurs, governments, and private businesses the opportunity to adjust their future plans and expectations.

WEC has no doubt that the starting of a dialogue among concerned stakeholders, the discovery of additional conventional and unconventional energy resources, the expansion in the use of renewables, the improvements in technologies, and the selection of optimal policies tailored to suit each region's needs will all ensure a sustainable transport future and will raise the quality of life for current and future generations.

1. Introduction

1.1 Background

The global transportation sector will face several unprecedented challenges over the next four decades (2010 through 2050). The world's population is expected to increase by 2.2 billion, reaching 9.2 billion, with more than two-thirds of the population living in cities compared to about half the population of today. In addition, the number of megacities is expected to increase from today's 22 to between 60 and 100 megacities by 2050. Many of these megacities, emerging mostly in Asia, Africa, and Latin America, will face high levels of traffic congestion, pollution, and noise. Furthermore, such an effect will be amplified by the two to three billion cars and trucks that could be in circulation. Over the same period, travel and road freight will at least double due to increased demand for transport, along with both economic development and improvements in standards of living.

Driven by increases in all travel modes, some sources expect the energy consumption of the transport sector to increase by between 80% and 130% above today's level. In addition, the transport sector alone could consume more than one third of global energy supplies (including more than half of all oil produced). Most of this demand is expected to come from regions undergoing strong economic and population growth (China, India, Russia, Latin America, and the Middle East).

Challenges relating to population demographics, urbanization, traffic congestion, local pollution, noise, and economics will all be compounded by uncertainties emerging from the unpredicted degree of government intervention and/or regulations, regional and global cohesions or cooperation, unpredicted global economic situations, and potential technology breakthroughs. In light of these challenges and uncertainties, the transport industry faces profound questions about how transport technologies and solutions could emerge in the next four decades, and how these may be able to satisfy the coming additional transport demands.

1.2 Study Goals

Capitalizing on the successful projects conducted in 1995, 1998 and 2007, the World Energy Council (WEC) has again decided to examine the future relationship between energy and transport, building Global Transport Scenarios out to 2050. This effort is undertaken in parallel with, and under the umbrella of, an energy scenarios exercise, but focuses solely on the transport sector. The aim of this project is to construct and describe potential global transport scenarios that reflect potential developments in transport fuels, technologies, and systems over the course of the next four decades.

The scenario approach has been adopted to describe the future of transport because other approaches, including long-term forecasting, are regarded as insufficient or even inadequate for addressing the vast uncertainties surrounding the world of transport. Unlike other tools, scenarios provide a set of plausible stories about different possible futures, taking into account uncertainties, critical factors, and driving forces. Furthermore, these internally consistent stories are intended to stimulate creativity in a challenging and yet plausible way. They are not to be considered as forecasts or exact quantification tools, but rather as instruments for learning.

1.3 Study Approach

To achieve this goal, WEC assembled a team on transport comprising 54 members from 29 countries. The first objective of the team was to identify and evaluate existing and potential fuel and transport technologies, both qualitatively and quantitatively. The qualitative assessment was intended to address current and potential developments in global transport systems at national and/or regional levels. The team used available information from completed and ongoing WEC studies and from proprietary and publicly available sources. To form the foundation for the study, the team also used case studies and quantified examples of available and emerging technologies and enabling policies. All this information was then compiled into a 150-page background document, which formed input for the scenarios on technologies, fuels, and transport systems.

Regional inputs on transport policies, local issues, and major driving forces were gathered during a series of regional workshops held, in Johannesburg, Bangkok, London, Thessaloniki, Washington D.C., and Rio de Janeiro. A series of transport questions was prepared for each workshop and discussed with local experts and WEC member committees. The insights from these workshops helped to form the assumptions for the development of transport scenarios through a bottom-up approach.

During a scenario-building workshop in London the information developed so far was used to create a working draft of two transport scenarios, looking out to 2050. The working titles of the scenarios are “Freeway” and “Tollway”.

To complete the study’s quantification requirements, WEC identified and commissioned the Paul Scherrer Institute (PSI) in Switzerland as a modelling partner. The two scenarios, along with the developed regional inputs, were translated into numeric assumptions and fed into PSI’s transport model.

This report starts with an overview of the global transport sector, along with discussion of the related major driving forces, constraints, and uncertainties. This is followed by descriptions of the two scenarios, Freeway and Tollway, and the regional inputs. The remainder of the report comprises the modelling results, concluding with key messages extracted from these results.

2. Overview of Global Transport Sector

In 2010, the global transport sector consumed about 2,200 million tons of oil equivalent (mtoe), constituting about 19% of global energy supplies. As Figure 1 shows, about 96% of this amount came from oil, while the rest was from natural gas, biofuels, and electricity. More than 60% of the oil consumed globally (around 51 million barrels per day) goes to the transportation sector. As the figure shows, road transport accounts for the bulk (around 76%) of the transportation energy consumption. The light-duty vehicles (LDVs), including light trucks, light commercial vehicles, and minibuses accounted for about 52%, while trucks, including medium- and heavy-duty, accounted for 17%. The remaining share of road transport was covered by full-sized buses (4%) and two-three wheelers (3%). Air and marine each accounted for about 10% of total transport energy consumption, while the railways accounted for only 3%.

Looking at these shares over a longer period of time, Figure 2 shows that road transport has always dominated the transport sector, followed by aviation and shipping.

Between1990–2006, global transport energy use grew at an average of about 1.8% a year for OECD countries, and about 2.8% for non-OECD countries (Table 1). As Table 1 shows, during this period, growth rates of transport energy use in OECD countries rose fastest for international aviation, followed by international shipping. For non-OECD countries, the fastest-growing energy use was by international shipping, followed by road transport (LDVs, trucks, buses, and two-three wheelers). However, looking at transport's energy consumption in more recent years, for example, between 2000 and 2006, it is clear that trends have significantly changed, since average growth for this period was about 1.2% for OECD countries and about 4.3% for non-OECD countries. The fastest-growing energy use in OECD countries was by international shipping, followed by rail, while for the non-OECD countries, the fastest growing energy use was international shipping, followed by international aviation, and then road transport.

Figure 1
2010 transport energy by source and by mode (total ~2,200 Mtoe)
Source: WEF, Repowering Transport, 2011

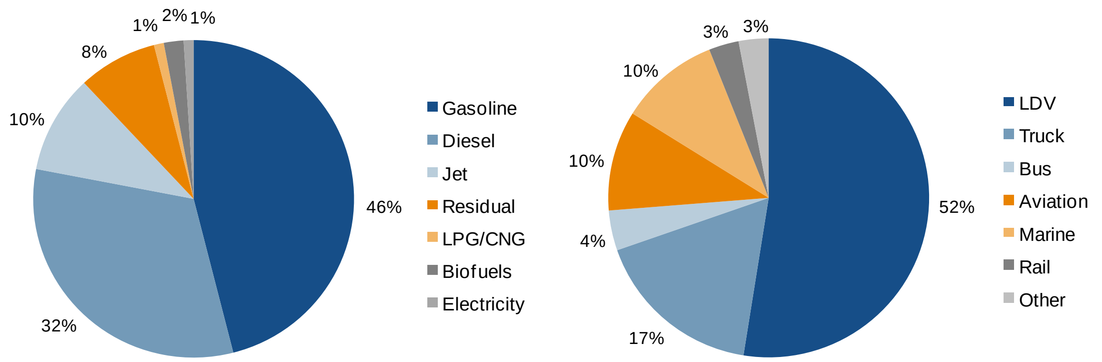
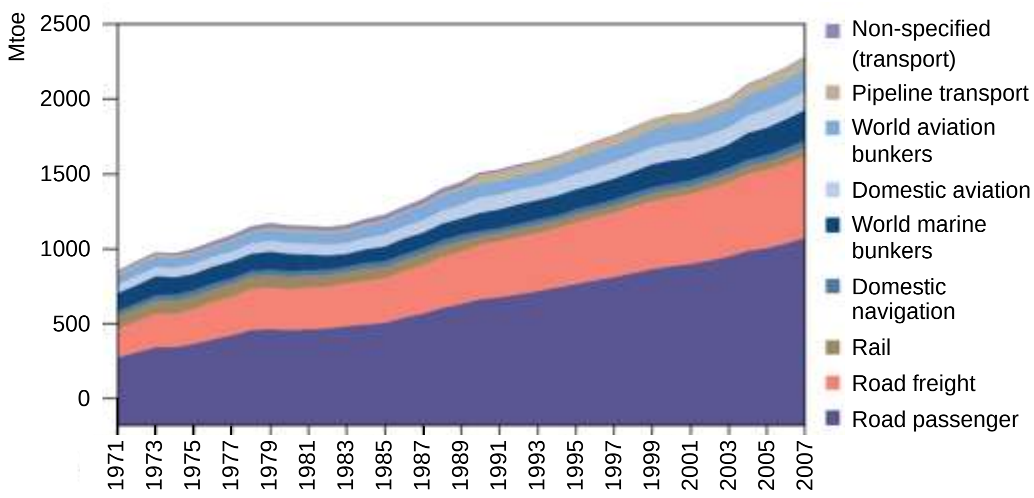


Figure 2

Global transport final energy use by mode (Mtoe)*

Source: IEA, Energy Technology Perspectives, 2010



Note: 1 toe = 6.5 to 7.9 boe, depending on the type of oil

Clearly, this growth in the use of transport energy closely follows the economic and population growth in the various regions. According to the World Bank, growth in real Gross Domestic Product (GDP) between 2000 and 2006 for OECD and non-OECD countries was 2.5% per year and 4.9% per year, respectively. As for population growth, over the same period, the World Bank stated that the OECD's population grew by 0.7% per year, while the non-OECD population grew by about 1.5% per year. If income and population continue to rise in the non-OECD countries, then it is likely that there will be a rapid growth in transport energy use. In contrast, for OECD countries, there are indications of saturation in certain travel modes such as LDV, since vehicle ownership seems to slow down despite economic growth cycles. Economic and population growth and the outlook of energy demand will be discussed further later in this report.

Despite steady growth in global energy use, various regions and countries show not only different energy-use growth rates per transport mode, but also different patterns in terms of both energy use per capita and type of fuel used (Figure 3). Some regions such as North America (except Mexico) consumed an average of over 2,300 tons of oil equivalent (mtoe) per 1,000 people in 2007, while others, such as parts of Africa, averaged less than 100 toe per 1,000 people. The figure also shows that OECD-North America, OECD-Pacific and Middle East depend heavily on gasoline as a transport fuel, while OECD-Europe, China, and Latin America depend heavily on diesel.

Table 1

Growth rates of transport energy use 1990–2006

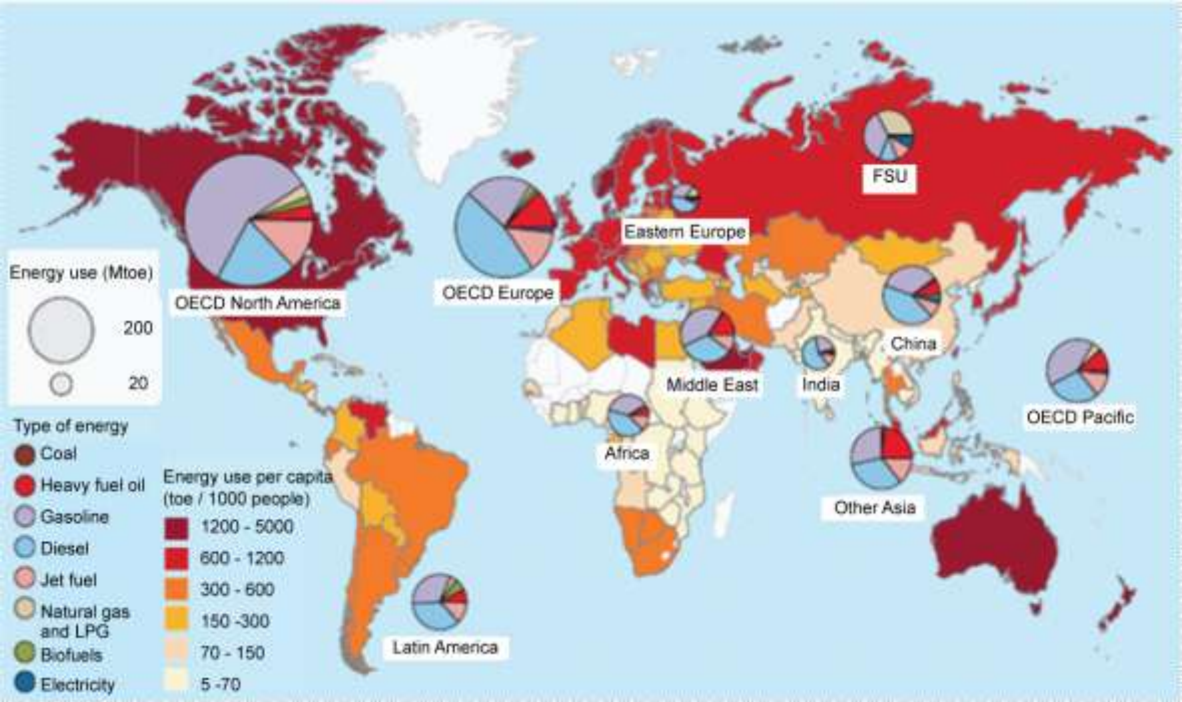
Source: IEA, Transport, Energy and CO_2, 2009

		OECD				Non-OECD			
Type of transport	**Year period**	**90-95**	**95-00**	**00-06**	**90-06**	**90-95**	**95-00**	**00-06**	**90-06**
	International aviation	4.4%	5.0%	1.2%	3.4%	-0.6%	1.7%	4.7%	2.1%
	Domestic aviation	-0.2%	2.5%	-0.3%	0.6%	-0.5%	4.9%	3.0%	2.5%
	Road	2.3%	2.1%	1.4%	1.9%	2.5%	2.9%	4.2%	3.3%
	Rail	-0.1%	-0.3%	2.3%	0.7%	-4.4%	2.9%	2.3%	0.3%
	International marine bunkers	1.1%	2.3%	2.5%	2.0%	4.6%	3.9%	5.4%	4.7%
	Domestic navigation	0.8%	0.5%	-1.0%	0.0%	-2.6%	6.5%	4.0%	2.6%
	Transport sector	2.1%	2.1%	1.2%	1.8%	1.1%	2.6%	4.3%	2.8%

Figure 3

Transport energy use by region in 2007

Source: IEA, Energy Technology Perspectives, 2010



Note: The figure reports final energy (end use), including the relevant allocation of energy use by international shipping, international aviation and pipeline transport.

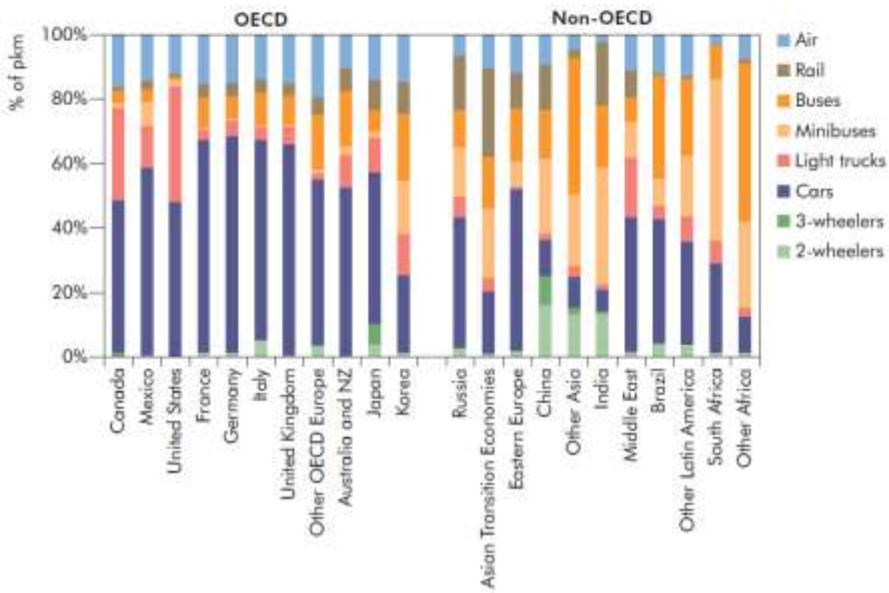
.

In addition to the differences in energy use per capita and the types of fuel used, different regions also employ different modes of travel (Figure 4). For example, OECD countries rely on passenger LDVs (cars, light trucks, and minibuses) much more than non-OECD countries, while non-OECD countries show higher shares for buses, rails, and two-three wheelers. Also, people in OECD countries undertake more air travel per capita than those of non-OECD countries.

Figure 4

Motorized passenger travel by mode in 2007

Source: IEA, Energy Technology Perspectives, 2010



3. Driving Forces

The two main drivers for energy demand in general, and transport specifically, are global economic and population growth. Indeed, demand growth could be constrained by geopolitical dynamics which can limit, in some cases, the supply of energy resources, and by concerns surrounding environmental and health issues. In response to these constraints, both consumers and governments are expected to take action to alter consumption lifestyles and introduce new regulations. Moreover, industries will respond with technological improvements, mainly in fuel efficiencies and alternative fuels. In this section, we address these driving forces, constraints, and responses in greater detail.

3.1 Economic Growth

The principal driver of demand for all energy sources is economic growth, namely the rate of GDP growth. In response to recent global financial and economic crises, most large economies introduced fiscal stimulus packages, involving tax reductions or spending increases, between late 2008 and mid-2009. Although these packages have helped mitigate the effects of the crises, they have also led to a ballooning of budget deficits and a sharp rise in national debt in many countries, especially in the OECD. Now many of these countries are faced with a need to tackle these debt problems. The fear remains that cutting debts may result in a slowdown of economic recovery (leading to a recession and debt spiral).

With growth prospects in the OECD countries likely to remain relatively weak for several years as they grapple with rising national debt, the emerging economies will remain the main drivers of the global economic recovery. The International Monetary Fund (IMF) suggests that the “sustained rapid growth” in the non-OECD countries will hinge on their ability to absorb rising inflows of capital and nurture domestic demand without triggering a new boom–bust cycle. In addition, the IMF acknowledges that the outlook for economic activity remains unusually uncertain, and risks are generally to the downside.

The risks to growth associated with the surge in public debt in the advanced economies are the most obvious, especially with respect to market concerns about sovereign liquidity and solvency in a few European countries (i.e., Greece, Italy, Spain, and Portugal), and the danger that these concerns could evolve into a full-blown and contagious sovereign debt crisis. The International Energy Agency (IEA) also expects that banks’ exposure to toxic assets (mortgages and household debt) could also threaten further turmoil in financial markets, particularly in the US and Europe.

The IEA’s outlook on economic growth assumes that the world economy will grow at an average of 4.4% per year over the years 2010 to 2015. According to the IEA, these growth assumptions are based on the IMF’s projections from the July 2010 update of its World Economic Outlook, with some adjustments made according to more recent information available for the OECD and other countries from national and other sources (Table 2).

Over the longer term, the rate of growth is assumed to slow, as emerging economies mature

Table 2
Real GDP growth by region (compounded average annual growth rates)
Source: International Monetary Fund and World Bank databases

	1980–1990	1990–2008	2008–2020	2020–2035	2008–2035
OECD	3.0%	2.5%	1.8%	1.9%	1.8%
North America	3.1%	2.8%	2.1%	2.2%	2.2%
US	3.2%	2.8%	2.0%	2.1%	2.1%
Europe	2.4%	2.2%	1.5%	1.8%	1.6%
Pacific	4.3%	2.1%	1.7%	1.2%	1.5%
Japan	3.9%	1.2%	1.0%	1.0%	1.0%
Non-OECD	3.3%	4.7%	5.6%	3.8%	4.6%
East Europe	4.0%	0.8%	3.0%	3.1%	3.1%
Caspian	-	2.0%	4.6%	3.2%	3.8%
Russia	-	0.6%	2.9%	3.1%	3.0%
Asia	6.6%	7.4%	7.0%	4.2%	5.4%
China	9.0%	10.0%	7.9%	3.9%	5.7%
India	5.6%	6.4%	7.4%	5.6%	6.4%
Middle East	-1.3%	3.9%	4.0%	3.8%	3.9%
Africa	2.3%	3.8%	4.5%	2.8%	3.5%
Latin America	1.2%	3.5%	3.3%	2.7%	3.0%
Brazil	1.5%	3.0%	3.6%	3.1%	3.3%
World	3.1%	3.3%	3.6%	2.9%	3.2%

and their growth rates converge with those of the OECD economies. As the table shows, the IEA expects that world GDP will grow by an average of 3.2% per year over the period 2008–2035, which is very similar to the rate between 1980 and 2008. The non-OECD countries as a group are assumed to continue to grow more rapidly than the OECD countries, driving up their share of world GDP. In several leading non-OECD countries, a combination of important macroeconomic and microeconomic reforms, including trade liberalization, more credible economic management, and regulatory and structural reforms have improved the investment climate and the prospects for strong long-term growth.

As a result of demographic factors and its state economic development, India is expected to overtake China in the 2020s and become the fastest growing region/country. Nevertheless, India's growth is expected to slow down from 8.1% in 2010–2015 to 5.6% in 2015–2035, while China's growth rate is expected to slow down from 9.5% in 2010–2015 to 3.9% in 2020–2035, less than half the rate at which it had been growing in recent years. Among the OECD regions, North America is expected to grow the fastest, at 2.1% per year on average over the projected period, sustained by more rapid growth in its population and labour force, and its lower debt in comparison with Europe and the Pacific region. Over the period 2008–2035, the IEA's base-case scenario expects economic growth to slow down in OECD and non-OECD regions, reaching 1.8% per year for OECD and 4.6% for the non-OECD.

3.2 Demographic Trends

Another critical driver for energy use is population growth. The United Nations projects the world's population to grow by 0.9% per year on average, from an estimated 6.9 billion in mid-2010, to 8.5 billion in 2035, and 9.2 billion by 2050. The population growth is expected to slow progressively over the projected period, in line with the long-term historical trend, from 1.1% per year in 2008–2020 to 0.7% in 2020–2035 (Table 3). In fact, the world's population has expanded by 1.7% per year from 1980 to 1990, and then by 1.3% per year between 1990 and 2008.

As the table shows, this population growth will not be evenly distributed, with most of the growth occurring in Africa, China, India, and parts of Latin

Table 3

Population growth by region (compounded average annual growth rates)

Source: United Nations Population Division and World Bank databases

	1980–1990	1990–2008	2008–2020	2020–2035	2008–2035
OECD	0.8%	0.7%	0.5%	0.3%	0.4%
North America	1.2%	1.2%	0.9%	0.6%	0.7%
US	0.9%	1.1%	0.9%	0.6%	0.7%
Europe	0.5%	0.5%	0.3%	0.1%	0.2%
Pacific	0.8%	0.4%	0.0%	-0.3%	-0.1%
Japan	0.5%	0.2%	-0.2%	-0.6%	-0.4%
Non-OECD	2.0%	1.5%	1.2%	0.8%	1.0%
East Europe	0.8%	-0.2%	-0.1%	-0.2%	-0.2%
Caspian	-	0.8%	1.0%	0.6%	0.7%
Russia	-	-0.2%	-0.4%	-0.5%	0.4%
Asia	1.8%	1.4%	1.0%	0.6%	0.8%
China	1.5%	0.9%	0.6%	0.1%	0.3%
India	2.1%	1.6%	1.2%	0.7%	1.0%
Middle East	3.6%	2.3%	1.8%	1.3%	1.5%
Africa	2.9%	2.5%	2.2%	1.7%	1.9%
Latin America	2.0%	1.5%	1.0%	0.6%	0.8%
Brazil	2.1%	1.4%	0.7%	0.3%	0.5%
World	1.7%	1.3%	1.1%	0.7%	0.9%

America. The increase in global population is expected to occur overwhelmingly, in non-OECD countries, mainly in Asia (China and India), and Africa (Figure 5).

The non-OECD population is expected to expand from 5.5 billion in 2008 to 7.2 billion in 2035 (its global share rising from 82% to 85%), which is the equivalent of an average growth rate of 1% per year. As the figure shows, Africa is expected to see the fastest rate of growth of about 1.9% per year. India is expected to overtake China towards the end of the projected period, and become the world's most populated country with 1.47 billion people.

Over the same period, the population of the OECD countries is expected to grow by only 0.4% per year. Most of the increase in the OECD occurs in North America, while the population of Europe will grow slightly. In contrast, the population in the OECD Pacific region is expected marginally to fall.

The United Nation's Population Division expects that all of the increase in world population will occur in urban areas, and the rural population will decline in most regions. It is worth noting that the world's urban population surpassed the rural population in 2009. The population living in urban areas is projected to grow from 3.3 billion in 2008 to 5.2 billion 2035 (an increase of about 1.9 billion), with most of this increase occurring in non-OECD countries. Continuing rapid urbanization will push up demand for modern energy services and transportation infrastructures.

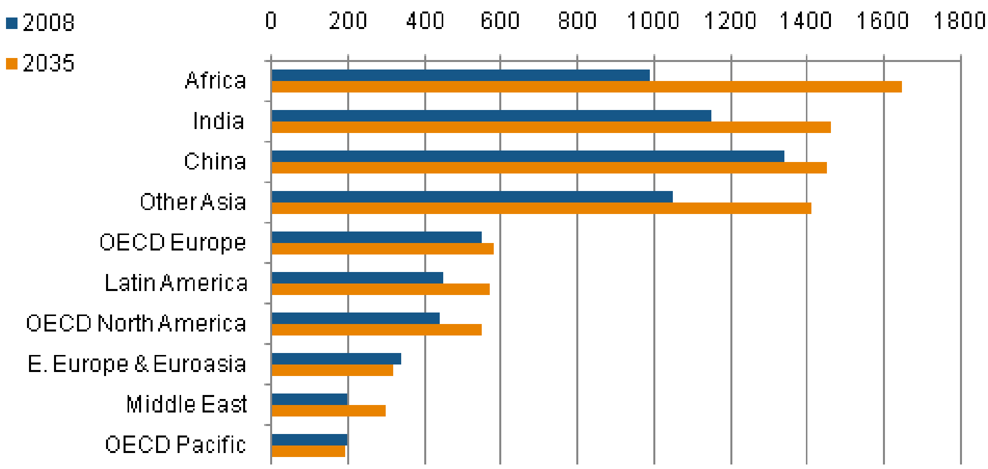
Such developments in population and hence demographics (household size and composition, and age structure) will have profound implications on the future of transport technologies and fuels, and even greater impacts on public policies that shape transport choices and options. In general, there are four global trends relating to population and/or transport that are anticipated to have the most significant impacts on transport future. These trends and their impacts are:

(1) The countries currently experiencing the highest population growth levels now have relatively low motorization levels in their current transport sectors, and often transport inequality between urban and rural populations and between rich and poor.

Figure 5

Population by major region

Source: United Nations Population Division and World Bank databases; IEA analysis



(2) Humankind has now reached a historic turning point where more people live in cities than outside them, with an increasing level of urbanization growth over the next four decades anticipated and the burgeoning of megacities with populations of over 10 million inhabitants.

(3) Much of the population growth from 2010 through 2050 will result in a shift to a "younger" demographic emerging in many developing, lower, and middle-income countries, while we witness an aging in the populations in many of the OECD nations and China.

(4) Most of the population growth rate over the next four decades will be concentrated in the countries and regions that have some of the lowest per capita GDP, which could make some forms of transportation too expensive at the consumer level (i.e., private car ownership), be a funding obstacle for the building of necessary infrastructure, and possibly reduce access to more expensive forms of energy-efficient technologies.

3.3 Urbanization and Megacities

Growth in both economic activity levels and population tends to result in surges of people moving into nearby cities, thus creating larger conglomerates and megacities. We believe that transport in megacities is one of the biggest challenges facing countries in the future. There is no magic bullet that will solve all of the transport challenges that these burgeoning cities will encounter. Although the UN defines megacities as those with populations over 10 million people, defining a megacity precisely is difficult. As cities have grown and merged with neighbouring areas, we now have cities proper, surrounded by metropolitan areas. As such, demographers have coined a new phrase: "urban agglomeration". An urban agglomeration is defined as an extended city or town area comprising the built-up area of a central place (usually a municipality) and any suburbs linked by a continuous urban area. Measuring the populations of megacities is extremely difficult because people are constantly moving into cities and current census data is very hard to come by. This is one of the reasons that the list of "largest cities" in the world is often debatable, and sometimes controversial.

For the first time in human history, more people live within cities than outside of them, and by 2025 the UN anticipates that two-thirds of the world's population will live in cities. The majority of megacities will emerge in Asia, Africa, and Latin America. In fact, the WEC's 2010 Energy and Urban Innovation study shows that in 2025 Asia will have 15 mega-cities, out of the global total of 27, since it accounts for more than half of the world's population. Megacities are problematic because we have never had this number of people, so densely packed, making demands on infrastructure and other resources. In 1950, there were only two megacities (New York and Tokyo); by 1975, there were three megacities (Tokyo, New York, and Mexico City); but by the year 2000, there were 18. From population estimates for mid-year 2010, this has risen to 22 megacities, as categorized by the UN (although some experts think that the number is closer to 30 megacities today).

We will see the growth of megacities in middle- to upper-level income countries slow during 2010–2050. However, the growth rates of megacities in low- to lower-middle income countries will increase. Furthermore, the implications are quite significant for transport, as the megacities that will experience the greatest growth rates are those currently classified as less motorized. This means that even a small increase in motorization levels for these megacities will have a profound effect on transport patterns, traffic, and congestion levels.

What will the number of megacities be in 2050? There is no consensus, but very large ranges. Some population experts expect that China alone will have 50 megacities by 2050. Estimates range between 60 megacities to over 100 megacities by 2050 globally. One of the major reasons why people migrate toward megacities is for employment and improved living standards. If these megacities become so dysfunctional in the future, some researchers suggest that people will leave for smaller cities, with improved economic opportunities and living standards. This theory would suggest that there is a type of “feedback loop” for megacities that could limit their size. Other researchers suggest that our current concept of megacities will need to be revamped and that megacities will hold between 25 and 50 million or more inhabitants. Another point of view on megacities suggests that there will be major worldwide declines in population growth due to economic and other conditions, with megacities peaking globally in 2050 and becoming “ghost towns” by 2100. There is even more controversy over which cities will be on the list by 2050 and in which order. At some point, these assessments become less and less valuable because of the various assumptions used in the modelling.

More salient to this study than the list and ranking of the largest megacities are the questions of what types of transport challenges they share and/or will encounter in the future, including:

(1) playing catch-up with infrastructure;

(2) making multiple forms of transport affordable, safe, and convenient to the masses;

(3) managing transport for the poor and urban slums;

(4) reducing congestion, pollution, accidents, and the overall negative effects on quality of life for inhabitants; and

(5) trying to change people’s traffic patterns so as to redistribute demands on infrastructure.

One trend appears clear for transport: megacities that currently have low levels of motorization are growing faster relative to megacities with high levels of motorization. Nearly 60% of the world’s populations live in less-motorized countries, and 62 of the largest cities in the world are categorized as less motorized.

Figure 6

Evolution of oil reserves, production, and consumption between 1989 and 2009

Source: Boeing, Global Geopolitical Trends: An Overview

3.4 Geopolitics

In energy geopolitics, the team has identified two major geopolitical drivers that could influence the energy scene during the many decades to come. These geopolitical drivers include the rise of China and the potential instability of oil supplies, and consequently oil prices, from specific regions.

Throughout the past decade, the rapid rise of oil and commodity prices has been associated, to a certain extent, with the rise of some emerging economies that heavily depend on natural resources. These economies were hit hard when oil prices fell as a result of the global economic crisis. In contrast, China appears to be on track for continued economic growth. As seen earlier, China's growth rate has averaged about 10% per year over the past 20 years, and is expected to average about 6% per year until 2035. With its relatively small debt, massive foreign reserves, competitive manufacturing centres, and growing consuming base, China is emerging as an economic powerhouse that is likely to remain strong over the long term.

China's emergence as a significant global player will reshape its relations with the US. Currently, China is the largest import market and third-largest export market for the US (creating a trade deficit of $230 billion in 2009). In addition, China holds around 23% of the US's foreign debt (more than $877 billion). These facts could cause some bilateral tensions between the US and China in the longer term. With its unique economic position, China will surface as a more influential player on global stage, and is likely to promote and protect its own interests. Other countries and regions, especially the US and European Union, will have to acclimate and accept China's rising economic and military influence.

The other geopolitical driver likely to play a major role in the energy future is the political instability observed in many oil supply regions. Political instabilities can potentially reduce, or even eliminate, oil production, causing disruptions throughout the global market. Undoubtedly, these distributions have immediate repercussions on oil price volatility, which creates serious consequences for the future of transport in the longer term. With 80% of the world's oil supply in the hands of National Oil Companies(NOCs), government actions such as investment restrictions can also reduce real and potential output in many countries such as Iran, Mexico, Venezuela, Nigeria, Indonesia, and Russia (Figure 6).

The team also expects that NOCs in resource-rich countries will continue to rise in power, take more aggressive positions in partnering with international oil companies, and limit further access to the natural resources in their countries. The wealth generated from this energy resource is expected to continue supporting the rapid development of many resource-rich regions, including the Gulf States, West Africa, Venezuela, and Russia. Unfortunately, this enormous wealth may exacerbate, in some cases, the problems often associated with valuable natural resources, government corruption.

Table 4

Proven and recoverable crude oil & NGLs reserves at end of 2008

Source: WEC, 2010 Survey of Energy Resources, 2010

Country	Billion barrels	Share of global	R/P ratio
Saudi Arabia	264	0.21	66.5
Venezuela	99	0.08	>100
Canada	22	0.02	18.6
Iran	137	0.11	83.5
Iraq	115	0.09	>100
Kuwait	101	0.08	99.6
United Arab Emirates	98	0.08	89.7
Russian Federation	79	0.06	21.8
Libya	44	0.04	65.5

3.5 Global Oil Reserve and Supply

Despite the doomsday predictions of the past decade, the good news is that the world's endowment of energy resources, both conventional and unconventional, is enormous. These resources, however, are becoming increasingly challenging and expensive to access, produce, convert, and deliver to where they are needed in a cost-effective, secure, and environmentally benign manner.

In its 2010 survey of energy resources, WEC estimated global proven reserves of oil and natural gas liquids (NGLs) at the end of 2008 to be around 1,239 billion barrels (Table 4). These conventional reserves were expected to last for another 41 years at 2008's consumption rate.

Despite the vast reserves that a few countries have, many countries have already experienced their peak oil, especially in Europe, Yemen, Syria, Australia, Uzbekistan, Gabon, Argentina, and the US. Evidently, the global oil supply is still expanding as presented in Figure 7. Some experts still see production from new frontiers, such as Kazakhstan, the deep waters in Brazil, and the oil sands of Canada, pushing production above the current plateau over the next few years. But time is running out to prove that newly discovered fields and new technology can more than compensate for flagging production from the rapidly aging fields beyond OPEC.

To relieve the squeeze on conventional petroleum supplies, many unconventional petroleum sources are being developed around the world. These unconventional sources include heavy and extra heavy oil (dense and viscous oil with large amounts

Figure 7

Global oil production (in thousand barrels per day)

Source: BP, Statistical Review of World Energy, 2011; EIA, 2010

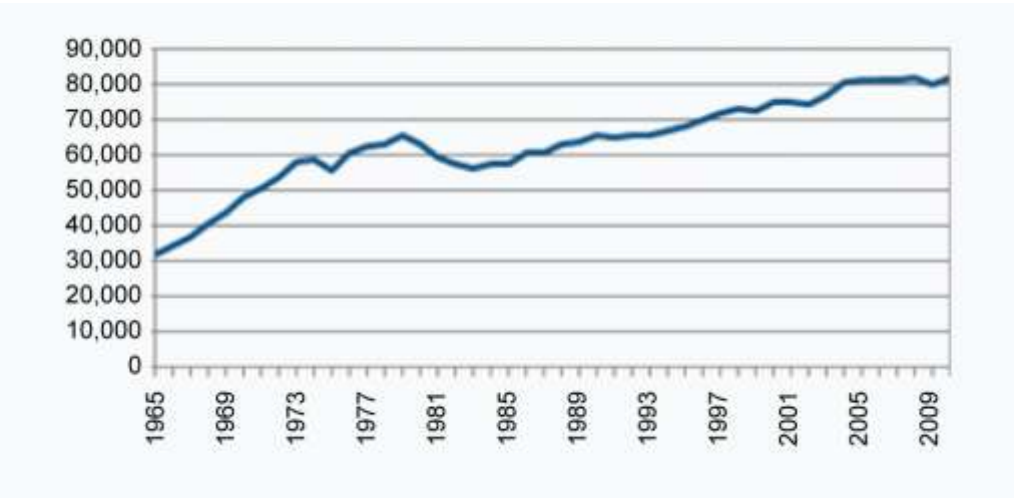


Table 5

Technically recoverable heavy oil and natural bitumen (billion barrels)

Source: USGS, Fact Sheet 70-03

Region	Heavy Oil		Natural bitumen	
	Recovery factor	Technically recoverable	Recovery factor	Technically recoverable
North America	0.19	35.3	0.32	**530.9***
South America	0.13	**265.7****	0.09	0.1
Africa	0.18	7.2	0.10	43.0
Europe	0.15	4.9	0.14	0.2
Middle East	0.12	78.2	0.10	0.0
Asia	0.14	29.6	0.16	42.8
Russia	0.13	13.4	0.13	33.7

*Mostly Canada, **Mostly Venezuela

of sulphur and metals); oil sands (mix of oil, sand, and bitumen); and oil shale (fine sedimentary rock containing oil and gas). According to the US Geological Survey's (USGS) estimates, the global recoverable heavy oil reserves are about 434 billion barrels of oil, 60% of which is located in Orinoco belt in Venezuela (Table 5). The USGS also estimates the global recoverable oil reserves from bitumen to be about 650 billion barrels of oil, most which is located in Canada. As for oil shale, deposits are located in many parts of the world, but the bulk is in the US. In fact, the US has about 75% of global oil shale, which equates to about 2,000 billion barrels of oil of a medium-quality Kerogen (yielding 40 litres of oil per ton of rock).

3.6 Environmental and Health Concerns

Despite the significant evolution of technology, energy efficiency, and policy options in the transportation sector since the early 1970s, the high volume of transport means (cars, planes, trains, etc.) still constitutes a major source of environmental and social concern. There are about seven types of environmental and social damage associated with transportation, namely air pollution, noise, congestion, climate change, upstream and downstream pollution (vehicles production and end-of-life), accidents, and costs of scarce infrastructure. Depending on the type of transportation mode (road, train, air, and waterway), some forms of damage are more prevalent than others.

The environmental and social costs of transport are currently analysed through the economic welfare theory and the concept of externalities. Although the great majority of studies of transport externalities discuss road modes, since it is by far the largest source of external costs within the transport sector, the other modes should also be discussed (Table 6).

3.7 Policies and Regulations

A broad range of policies already exists and addresses many challenges at various stages of the transportation-related technology lifecycle. Many policy types are mutually complementary, while some others may overlap. A greater synergy between these policies can lead to more effective technology development and deployment. These policies may be economic, command and control, or information-related.

Economic policies include fuel taxes, carbon pricing, and subsidies in research and development (R&D), infrastructure, production and consumption. The effects of fuel taxes and carbon-pricing mechanisms can have an immediate impact and reduce consumption more effectively. Although these two policies have significant long-term gains, they are both politically difficult to implement due to their highly visible and upfront costs. Subsidies in the R&D phase are critical, since they are the only policy that can overcome the challenge of short, private, and high-risk investments.

Table 6

Specification of different costs according to transport modes

Source: CE Delft, Handbook on estimation of external costs in the transport sector, 2008

Costs	Road	Rail	Air	Water
Scarce infrastructure	Individual transport is causing collective congestion, concentrated on bottlenecks and peak times	Scheduled transport is causing scarcities (slot allocation) and delays (operative deficits)	Scheduled transport is causing scarcities (slot allocation) and delays (operative deficits)	If there is no slot allocation in ports/channels, congestion is individual
Accident costs	Level of externality depends on the treatment of individual self-accidents (individual or collective risk).Insurance covers compensation of victims (excluding value of life).	Difference between driver (operator) and victims. Insurance is covering parts of compensation of victims (excluding value of life).	Difference between driver (operator) and victims. Insurance is covering parts of compensation of victims (excluding value of life).	No major issue
Air pollution	Roads and living areas are close together	The use of diesel and electricity should be distinguished	Air pollutants in higher areas have to be considered	Air pollutants in harbour areas are complicated to allocate
Noise	Roads and living areas are close together	Rail noise is usually considered as less annoying than other modes (rail bonus). But this depends on the time of day and the frequency of trains.	Airport noise is more complex than other modes (depending on movements and noise maximum level and time of day)	No major issue
Climate change	All GHG relevant	All GHG relevant, considering use of diesel and electricity production	All GHG relevant (air pollutants in higher areas to be considered)	All GHG relevant
Nature and landscape	Differentiation between historic network and motorways extension	Differentiation between historic network and extension of high-speed network	No major issue	New inland waterways channel relevant

These subsidies target long-term results (e.g., more efficient fuel use in the long term) and can lead to the creation of breakthrough technologies. Subsidies can also take place in infrastructure. Similarly, subsidies, or incentives, for production and consumption can also have high impact, especially towards the adoption ofa technology. These subsidies can take many forms, including direct financial subsidies (to either manufacturers or consumers for each vehicle bought or sold), indirect financial subsidies [free parking for fuel-cell vehicles (FCVs) or electric vehicles (EVs), congestion charge waivers], or non-financial form (driving lanes). Politically, these subsidies are easy to operate and implement.

Command and control policies performance standards, technology or process mandates, and enabling standards. Performance standards can be highly effective if properly designed. These policies can mandate an outcome, while allowing market forces to determine the best technologies to reach it. Although they are typically quite easy to enforce, it is surprisingly complex to design standards that avoid creating perverse incentives.

Technology or process mandates are also considered command and control policies. These policies are moderately effective and can have high impact during the adoption phase and where there is a strong link between a technology and a desired outcome. Technology or process mandates are fairly difficult to implement. The mandates are often expensive to enforce (i.e., building emissions-testing stations) and politically difficult to implement, given the contrasting interests of some industry groups (in short-term results) and consumers and society (in long-term impacts).

Finally, information policies include labelling and consumer-education campaigns. In general, the impact of these policies is moderate but rather quick. These types of policies focus on educating consumers, making them aware of information. A good example is the US's national tire fuel efficiency education policy.

3.8 Lifestyle Changes

Predicting the impact of lifestyle changes on transport choices is hard and the predictions are rarely proved right. As inspiration for future predictions, we can look back to past ideas of what transport would look like today. Now they appear to have been overly ambitious, full of futuristic flying craft instead of cars.

One reason for this is the idea that new technologies will completely shift or replace older ones. This is unlikely: for example, the proliferation of information technology has affected some of our transport patterns, but not completely changed them or made them obsolete. People still make physical journeys even though they can use telecommunications to have virtual meetings. A more realistic approach suggests that there will be a shift from one type of transport to another. For example, the increase in online shopping in the US has resulted in more delivery vehicles being used. However, even though online purchases have grown astronomically, the overall number of miles driven per year by the average American has not changed. Sometimes technologies are additive and not subtractive.

To have very profound effects on transport is ultimately difficult, but, having some impact on the margins is more achievable. For example, telecommuting can reduce—to some extent—the need to commute physically. However, even with the increase in telecommuting, we will not necessarily see any sizeable decrease in the aggregate level of miles driven in countries like the US. What we might see instead is shifts in the times at which people are driving on the roads.

While there is a current belief that "going green" will massively change transport choices, we believe that effect may be exaggerated. Although green choices, such as using hybrid vehicles or electric vehicles, may be available and popular in relatively wealthy countries these may not be an option in places like sub-Saharan African countries, because of their cost.

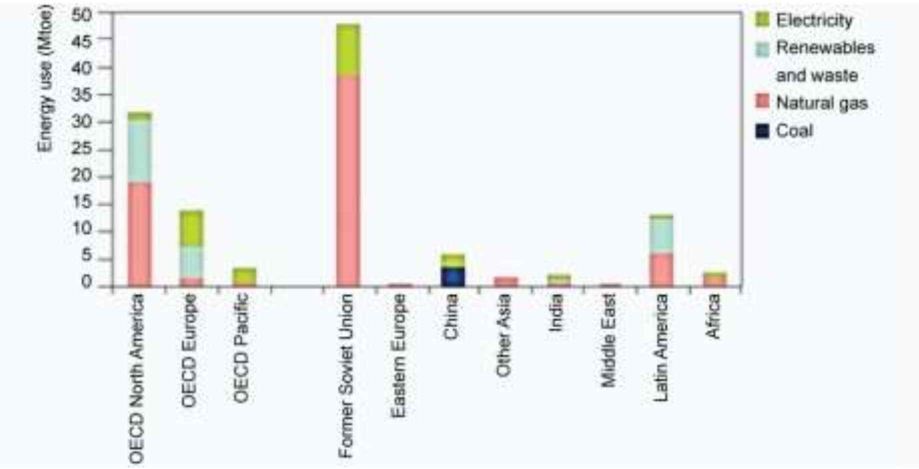
We believe four lifestyle factors have been ignored and need to be addressed in any transport scenarios, in addition to information technology/telecommunications and the adoption of green consumer patterns. These factors are:

- Gender issues: In countries with greater gender equality, more women are mobile, more women work outside the home, and they utilize more types of transport. The

Figure 8

Non-oil-based fuel use by region in 2005

Source: IEA, Energy Technology Perspectives, 2010



emergence of more women working outside of the home could have a profound effect, especially in countries that currently have low motorization rates. Additionally, changes in views about women driving in specific countries/regions of the world could have a very significant impact on transport patterns.

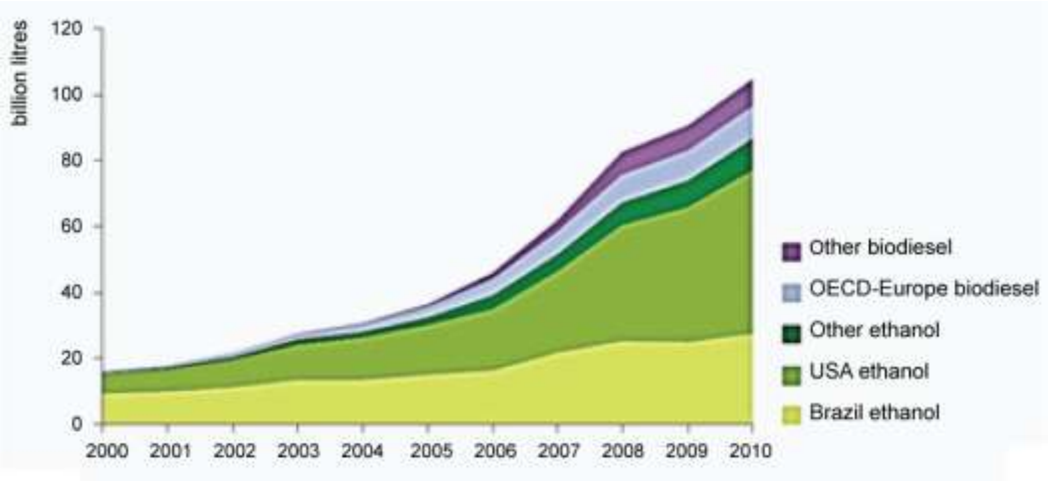
- Access to reliable electricity: Without reliable electricity, telecommunications and information technology suffer. Furthermore, the idea of using electric vehicles will not work in the many places that do not have access to electricity or have frequent black- and brown-outs.
- Leap-frogging technologies: This concept suggests that countries can accelerate development by skipping inferior, less efficient, more expensive or more polluting technologies and industries, and moving directly to more advanced ones. A successful example of this is the use of cellular phones instead of landline phones.
- Income-transport gap: One of the most significant transport challenges the world faces is how to offer reliable, safe, and affordable choices of transport to an expanding number of poor people. The income-transport gap is the gap between those that can afford transport choices and those with no transport choices. Dealing with the income-transport gap will be essential in the megacities of the future, in order to help manage pollution and environmental degradation.

3.9 Alternative Fuels

Transport fuel-use worldwide is currently dominated by oil products, with more than 96% of fuels comprising conventional gasoline or distillate fuels (including conventional diesel and kerosene or jet fuel). However, some countries use significant amounts of Natural Gas (NG), electricity, and biofuels. Focusing on the non-oil-based fuels in these countries/regions, we can see from Figure 8 that most of the biofuels are consumed in OECD-North America (especially the US) and Latin America (especially Brazil). As for electricity, it is extensively used in passenger rail systems in Europe and the former Soviet Union (FSU). China's passenger rail systems mainly use coal. Hydrogen, gas-to-liquid (GTL), and coal-to-liquid (CTL) are not used in great volumes to fuel the transport sector except in South Africa.

As biofuels and NG are the two most promising alternative fuels, we will limit discussion in this section to these two. Biofuels include bioethanol, biodiesel, and biogas. In 2010, the global biofuel production reached 100 billion volumetric liters (about 1.7 million barrels per day), which amounts to about 2% of the global transport fuel (Figure 9). As can be seen from the figure, most of this was ethanol, used by the US and Brazil, and the rest was biodiesel. These biofuels already constitute large market shares in some countries (20% in the US and 10% in Brazil).

Figure 9
Global biofuel production 2009–2010
Source: IEA, Technology Roadmap, Biofuels for Transport, 2011



In 2009, the IEA estimated that by 2030 consumption of biofuels will reach about 93 Mtoe, accounting for about 5% of the total road-transport fuel demand, compared with approximately 2% today (Table 7). This means the average annual growth rate will be about 7%. As the table shows, the demand for biofuels will grow all over the world, especially in developing Asia and Africa, while the US and Europe are expected to remain the biggest consumers.

Although the international trade in biofuels is also expected to increase significantly, the majority of biofuels will continue to be produced and consumed domestically. In fact, bioethanol will remain the dominant biofuel and will account for the major share of exports. Brazil is expected to remain the leading bioethanol exporter for the coming decades. Besides the Americas and Europe, countries in Africa and Asia (especially China) have the potential to become major producers and exporters of biofuels.

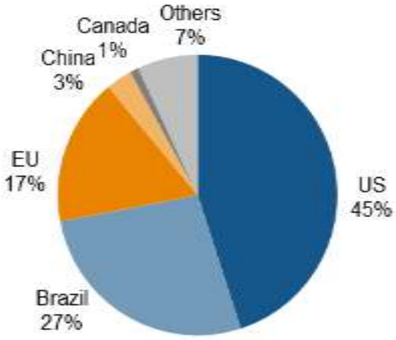
Table 7
World biofuel consumption (million ton of oil equivalent)
Source: WEC, Biofuels: Policies, Standards, and Technologies, 2010

	2004	2010	2015	2030
OECD	**8.90**	**30.50**	**39.00**	**51.80**
North America	7.00	15.40	20.50	24.20
USA	*6.80*	*14.90*	*19.80*	*22.80*
Canada	*0.10*	*0.60*	*0.70*	*1.30*
Europe	2.00	14.80	18.00	26.60
Pacific	0.00	0.30	0.40	1.00
Transition Economies	**0.00**	**0.10**	**0.10**	**0.30**
Russia	*0.00*	*0.10*	*0.10*	*0.30*
Developing Countries	**6.50**	**10.90**	**15.30**	**40.40**
Developing Asia	0.00	1.90	3.70	16.10
China	*0.00*	*0.70*	*1.50*	*7.90*
India	*0.00*	*0.10*	*0.20*	*2.40*
Indonesia	*0.00*	*0.20*	*0.40*	*1.50*
Middle East	0.00	0.10	0.10	0.50
Africa	0.00	0.60	0.10	3.40
North Africa	0.00	0.00	0.10	0.60
Latin America	6.40	8.40	10.40	20.30
Brazil	*6.40*	*8.30*	*10.40*	*20.30*
World	**15.50**	**41.50**	**54.50**	**92.40**

Figure 10

World biofuels production

Source: WEF, Repowering Transport, 2011



A competitive biodiesel production and export business could develop in Southeast Asian countries that are large palm oil producers. However, their success would depend to a large extent on both domestic subsidies and international trade rules. Looking at the global biofuels production in 2009, we can see from Figure 10 that the US dominated producing 45%, followed by Brazil with 27%, and the European Union (EU) with 17%.

A wide variety of conventional and advanced biofuel technologies exists today. Some of these biofuel technologies are already commercially available, while others are still in the demonstration phase (Figure 11).

The future of biofuels (bio-ethanol, biodiesel, bio-butanol, and bio-gas) will be constrained by many factors, including the use of available arable land, the efficiency of agricultural production methods, the development of more advanced biofuels technologies, and developments in the global oil market. The future success of biofuels will depend on two major factors: the expansion of cultivated land, and increases in agricultural technologies and productivity. These will require a broad political commitment, including introduction of land reforms; better irrigation; advancing biotechnologies; improving plant yields; more efficient use of fertilizers; and improvements in transport infrastructure. The development of second- and third-generation biofuels from non-food sources would limit the current competition between the production of crops for food and for biofuels, respectively.

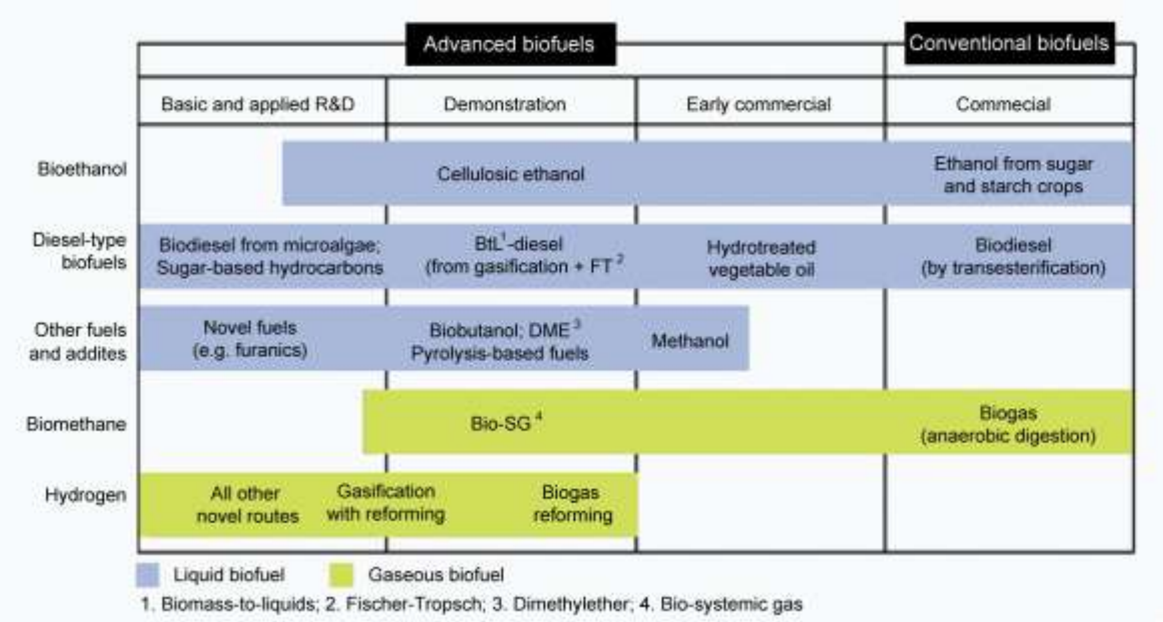
In 2008, the United Nations' Food and Agriculture Organization (FAO) estimated that biofuels were responsible for about 10% of the food-price increases around the world. In certain countries, biofuels have had a significant impact on food prices, but this was mainly because of national agricultural support programs and protectionist measures, rather than increased production of biofuels. The UN also suggested that current biofuel subsidies and trade barriers exercised by OECD countries benefit producers in OECD countries at the expense of producers in developing countries. The UN report The State of Food and Agriculture (2008) states that the "expanded use and production of biofuels will not necessarily contribute as much to reducing greenhouse gas emissions as was previously assumed," and that "changes in land use— for example deforestation to meet growing demand for agricultural products—are a great threat to land quality, biodiversity, and greenhouse gas emissions".

Apart from biofuels, natural gas (NG) is another key alternative transportation fuel. According to the International Association of Natural Gas Vehicles (IANGV), the compressed natural gas (CNG) vehicles base has already reached significant size, estimated at 11.4 million vehicles in 2009 (mainly in Pakistan, Argentina, Brazil, Iran, and India). Similarly, and according to the World LP Gas

Figure 11

Conventional and advanced biofuels

Source: IEA, Technology Roadmap, Biofuels for Transport, 2011



Association (WLPGA), the liquefied petroleum gas (LPG) vehicles have also captured a significant market share of about 16 million vehicles in 2011 (mostly in Turkey, South Korea, Poland, Italy, and Australia), which represents about 3% of the global passenger car fleet.

Natural gas as a fuel has several advantages compared to gasoline and diesel as it emits less CO_2, is cheaper, more abundant, and has more widely spread supplies. However, along with these advantages, there are a few disadvantages to this fuel, including that the efficiency of NG-engines is lower than that of standard gasoline and diesel internal combustion engines, and they also tend to be more expensive.

3.10 Fuel Efficiencies

Global vehicle standards are in the midst of dramatic changes now. The four largest automobile markets—the US, the EU, China, and Japan—each approach the regulation of fuel economy quite differently. The US is currently changing the way it will regulate vehicular emissions. It used to regulate vehicles based on corporate average fuel economy (CAFE) standards, which required each manufacturer to meet specified fleet average fuel economy levels for cars and light trucks, respectively. However, policy makers are now shifting to a “footprint-based” approach and looking for a way to regulate greenhouse gas (GHG) emissions instead of fuel economy. Under the new approach, individual vehicle fuel economy or GHG targets are based on the size of the vehicles. As such, each automaker now has its own fuel economy target based on the average size of the vehicle fleet. In Japan and China, fuel economy standards are based on a weight classification system, where vehicles must comply with the standard for their weight class. Fuel-economy standards in the Republic of Korea are based on an engine-size classification system. China is following the New European Driving Cycle (NEDC) testing procedures developed by the EU. The Republic of Korea is following testing methods similar to US CAFE procedures. Japan maintains its own test procedures.

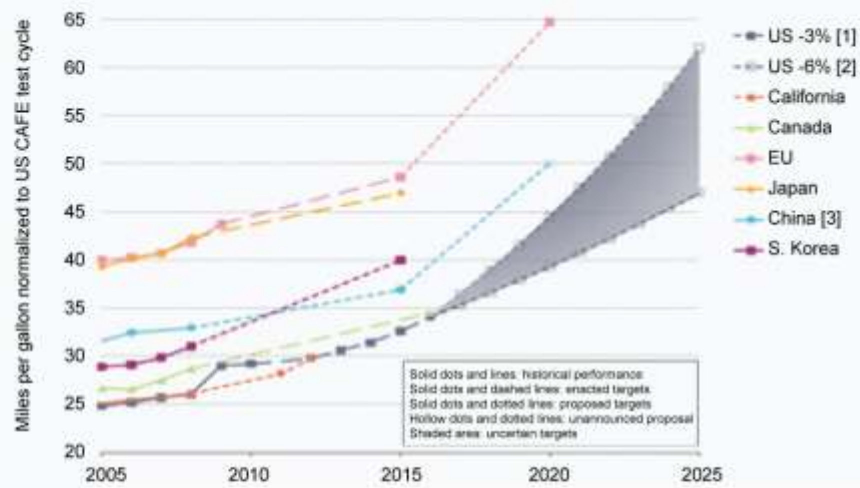
The EU is also changing its fuel-economy policies. Until 2009, the EU promoted a voluntary standard. However, as it became increasingly evident that automakers were not going to achieve the voluntary standard, it was made mandatory, and is now based on a weight-based-limit value curve.

Figure 12 shows the comparison of actual and projected fuel economy for new passenger vehicles for the US, the EU, Japan, China, Canada, and Korea (Republic). Dashed lines represent proposed

Figure 12

Comparison of actual and projected fuel economy for new passenger vehicles

Source: Pew Centre on Global Climate Change



standards under development. The figure shows that the EU and Japan still have the most stringent standards, and that the US has the weakest standards in terms of fleet average-fuel-economy rating. However, the developmental trends for dramatically improving vehicle fuel-economy among major nations are very clear, even though each country's timeframe is different.

In response to these challenging new fuel-economy standards, higher fuel prices, and tighter emissions controls, transport manufacturers are motivated to find new ways to improve efficiencies and make transport more affordable. In the long term, the Energy Information Administration (EIA) expects that manufacturers can potentially achieve a reduction of about 28%–33% for the conventional ICE engines, 41%–45% for the hybrids, and about 54%–55% for plug-in LDVs. Evidently, additional range economy can be realized via improvements that include aerodynamic streamlining, improvements in tyres' rolling resistance, improved lighting, improved air-conditioning systems, and optimization of the vehicle's body using composite materials. Improvements in trucks, buses, aviation, and shipping are expected to improve fuel efficiency in the long run too.

3.11 Innovations

Numerous studies on the future of transportation envision that conventional forms of transport will no longer be used 50 years from now. The proposed alternative transport solutions range from fully electric vehicles to hydrogen-fuelled individual and mass rapid transit systems. As the trend towards increasing urbanization becomes stronger, cities will be forced to adopt intelligent public transport solutions that will reduce both congestion and pollution. Some of the solutions planned for the future have their roots in concepts and pilot projects being developed and tested today. The following are a few examples of innovative transport solutions that may grow to scale in 40–50 years' time.

Car-sharing companies are becoming increasingly popular. The business model spans for-profit, non-profit, and cooperative areas. As the name suggests, car sharing works on the principle that cars are hired in an urban area by picking them up from selected spots and paying for their use, before returning them to designated areas. Prices are structured on an hourly basis or a per-day basis. Car sharing has its beginnings in Europe about 30 years ago, but has only become commercial in the last decade. The largest car-sharing company today is Zipcar, headquartered in Cambridge, Massachusetts, US. The company operates in the US, Canada, and UK, owns more than 9,000 vehicles, and has 605,000 members. In 2010, Zipcar acquired the UK car-sharing company Streetcar for $50 million. Other companies have also entered this spac, including like Dailmer AMG with their car2go project (2008), which operates in the US (Austin, Texas), Canada (Vancouver), and

Germany (Hamurg, Ulm). BMW and SixtAG have also entered this sector with the rollout of their DriveNow enterprise (2011), which currently operates in Munich and Hamburg. In addition to independent companies and automobile manufacturers, traditional car-rental agencies like Hertz are also entering the car-sharing market. Other smaller car sharing programs/companies also operate in US (e.g., City CarShare, Mint, eGo CarShare, I-Go, Hourcar, Philly Car Share, Austin Car Share, Buffalo Car Share, Community Car, U Car Share, Car Share Vermont, Ithaca Car Share, We Car); Canada (e.g., CommunAuto, Victoria Car Share Co-op, Co-operative Auto Network, VRTUCAR, AutoShare Car Sharing Network, The People's Car Co-operative, Car-Sharing Co-Op of Edmonton, CarShare HFX, Grand River/Hamilton Car Share, Nelson Car Share Cooperative); Australia and New Zealand (e.g., Cityhop, GoGet Australia, Newtown CarShare, CharterDrive, Flexicar); and Europe and the UK (e.g., European Car Sharing, Mobility CarSharing Switzerland, CARvenience, HOURCARS Salisbury, CampusCars, CamShare, Copenhagen Car Sharing). The car-sharing sector is growing in Europe for a number of reasons; including freedom from car ownership and implied costs, ease of use, inability to own a car outright, environmental awareness, and choice of vehicles.

Rapid transit systems fall into three categories—bus rapid transit (BRT), personal rapid transit (PRT), and group rapid transit (GRT). BRT is used mainly in Brazil and China, where bus fleets operate on dedicated roads or road sections. This allows buses to operate with high frequency and minimum delays. However, at present, BRT is competing with an increasing number of cars for road space. PRT is also called a “podcar”. It is a public transportation mode featuring small, automated vehicles, allowing for a maximum passenger capacity of six persons, operating on a network of specially built guide ways. . Currently, there are three operating PRT systems—Morgantown (US), Masdar City (Abu Dhabi), and London Heathrow (UK). They are all in test phase, and plans are being made to grow them in scale if the pilots are successful. GRT is similar to PRT, but with higher occupancy. It can be used in areas of high density with more-or-less average peak-time travel.

The application of superconductivity to rail transport has the potential to cut conventional rail-travel times by more than half and reduce CO_2 emissions by two-thirds. Average cruising speed is estimated to be 500kmph. Japan is planning to connect Tokyo, Nagoya, and Osaka via SCMaglev, which will be financed and built by JR Tokia (Central Japan Railway Co.). High-Speed Rail (HSR) projects are also being built in China, Turkey, Russia, Spain, and other countries. The US has a high potential for HSR, but needs to find political acceptance before any plans are made.

3.12 Summary

A wide spectrum of critical trends are significant for this study, some of which are regarded as predetermined factors, such as population growth, while others, such as lifestyle changes and geopolitical dynamics, are more difficult to predict. Although economic growth is regarded as a predetermined element, it is linked to uncertainties such as the exact level of economic activity and the question of how economic growth may be linked to economic liberalization and internationalization of trade. The discussion also revealed that changes in demographics are also highly predictable in light of a predetermined economic growth element. The interaction between these two, economic growth and demographic change, adds more complexity to the transport picture, as new megacities develop.

As a constraint, the investigation of energy geopolitics recognized the rise of China as a major power competing for dominance and resources. In addition, oil supply will not be a real constraint throughout the study's time horizon. The future of the oil price will be determined by supply, demand, and political events around major oil producers.

Health and environmental concerns will also play a significant role in shaping the future of transport. Certainly, how these play out will depend on the levels of cooperation among and between consumers and governments who will most probably respond with new policies regarding efficiency, congestion, and emissions. Businesses and industries will also respond to these concerns, probably by increasing the efficiency of the various transport modes and offering new technologies and alternate fuels.

4. Critical Uncertainties

4.1 Government Regulation

The link between the form of political establishments and their economic governance has always been the subject of debate. Evidently, any government form—democratic, authoritarian or anything in between—can either be credited with or accused of a certain economic performance depending on the extent of the role it plays in deciding market rules. On the one hand, government policies may allow and/or promote the behaviour of free and competitive markets; on the other hand, a government may intervene heavily to regulate markets and aspire to attain certain outcomes via dictating market rules.

Theoretically, that government role can be reflected in three ways.

(1) A government may be described as "engaged" if it is not only fully aware of the market trends, issues, and requirements but also ensures that required actions are taken to reach optimal results.

(2) A government may be described as "involved" if it carries few responsibilities and leaves the rest to the market. This role could be viewed as suboptimal as it has the potential to introduce imbalances in market powers if the government competes with other providers.

(3) Finally, a government may be described as "interfering" with actions or regulations that could sometimes be inefficient or even obstructive.

As discussed earlier, under policies and regulations, governments can deploy many economic, command and control, and information policies, which can influence markets dramatically. With regard to transport, governments can impose fuel taxes, carbon pricing, subsidies, performance standards, technology or process mandates, enabling standards, and labels, or it can even dictate consumer education campaigns.

As governments quite often change their roles in regulating markets, this project considers the government role as quite uncertain. Therefore, the scenarios focus on two extremes of market regulation:

(1) "Competitive market" where governments are minimally engaged; and

(2) "Centrally planned market" in which the government is heavily involved in regulation.

4.2 Cooperation-Integration

The second key source of uncertainty in describing the future of transport study arises from the degree of cooperation–integration between the market players, including individuals, public, corporations, and governments, on bilateral, regional, or even international levels. Such cooperation–integration originates from the recognition of mutual benefits, along with the need to share resources, suffer consequences or realize gains, or plan a sustainable future for all. As with the description of government regulation above, the cooperation–integration uncertainty has three basic possible positions. It could be in the form of

(1) an agreement between companies,

(2) a partnership between public and private, or

(3) an international agreement between two or more international governments.

Theoretically, these agreements and/or partnerships would further facilitate the exchange of resources (labour, capital, raw materials, or financial) and technologies.

In our scenarios, and in the same way as the WEC's energy scenarios (2007), this study also considers the degree of cooperation–integration as uncertain because is unclear what politics/economics-related barriers could be erected to defend private, public, or even national interests. In contrast, the new global free market governed by rules of trade is expected to liberate markets, remove barriers, and promote cooperation–integration.

5. Transport Scenarios

In a world with such critical drivers and uncertainties, binding constraints, and unravelling responses, the transport and mobility team has mapped out two potential scenarios for global transport, called "Freeway" and "Tollway."

5.1 Freeway

Freeway envisages a world where market forces prevail to create a climate for open global competition, higher levels of privatization, deregulation, and liberalization. It also stimulates the role of the private sector, entrepreneurs and global companies so that they emerge as central players in a new international trading environment without trade barriers.

Despite successful international coordination and cooperation on free market mechanisms, there are still a few trade disputes and global trade is highly imbalanced. In the same way as goods and services can move freely through the open global market, capital enjoys more freedom to move, and this incentivizes foreign direct investments (FDIs) to higher levels. Private financing capital is available, abundant, and easy to secure. Market-driven technology innovation also prospers and emerging innovation centres attract and compete for investment capital and human resources. In most countries, investment in infrastructure remains limited to just a patchwork of improvements, as capital is directed to more profitable channels. Efforts in R&D sectors are driven by both private and public sectors and remain diverse.

During good economic situations (at the top of the cycle), this scenario is characterized by high but unevenly distributed economic growth, with sufficient funds for new private investments. In a bad economic situation (at the bottom of the cycle), this scenario is characterized by low and unevenly distributed economic growth with widespread austerity packages, reducing new investments and energy demand. In both economic situations, the income per capita remains high and increases, especially in the western world and successful new industrial regions (Southeast Asia, Latin America, and the Caribbean); Africa remains marginalized. Consumer spending increases while savings drop. Market distortions including corruption, bureaucracy, tax regulations and subsidies decrease in many regions with some remaining subsidies in renewables.

In the energy sector, many countries have opened their upstream sectors, resulting in a surge of supply and more security of supply for consuming nations. Oil prices remain moderate in the short term, but high growth in energy demand leads to higher prices by the end of the scenario period. Reliance on fossil fuel falls but rather more gradually. Industrial demand for energy reaches an all-time peak, and electricity prices increase sharply, leading to greater energy poverty.

This scenario yields more individual transport solutions that are more short-term and lacking wide perspectives. Evidently, higher economic growth results in more vehicle ownership and increased traffic and freight movement, especially in eastern markets. Improvements in high efficiency ICEs continue and more hybrid cars penetrate the LDVs market. CNG vehicles gain ground only where gas reserves became accessible by IOCs. For EVs, batteries have remained expensive but with time, R&D drives the price down. The competitive market incentivizes new business models for battery replacement. Innovation centres in eastern markets and megacities drive the introduction of larger numbers of EVs, prompted by to air-quality concerns. In the longer term, low-cost EVs penetrate western markets. FCVs make only a small breakthrough as they are still expensive. Crude oil remains necessary to fulfil the bulk of transport demand throughout the scenario period. In the biofuels market, the food crisis depresses global biofuels growth. The strongest regional hubs for biofuels remain North and South America (US and Brazil); second- and third-generation biofuels remain expensive.

5.2 Tollway

Tollway is best described as a regulated world where governments and prominent politicians decide to put common interests at the forefront and intervene in markets. In such an environment, the more fragmented and differentiated global economy suffers weak cooperation on free-market mechanisms, which results in more trade restrictions. However, the world as a whole has witnessed increasing international cooperation on climate-change issues in the short to medium term.

As is the case with the movement of goods and services, capital also suffers limited movement, forcing FDIs to drop to lower levels. Private financing capital is more limited and is supplied mostly by local institutions. Large public sector funding is limited to infrastructure and “green” projects. As for technology, governments have picked only the technology winners (e.g., photovoltaic). Technology transfer has been facilitated mainly by international research programs and technology “clearing houses”. Investment in infrastructure has enjoyed a boom as governments fully fund public projects, especially public transportation and renewable energy. Governments have also given greater focus to, and exerted more international efforts towards, climate change in the short, medium, and long term. The world witnesses less competition over energy resources given regionalized markets and improvements in energy efficiency. There remains the risk of political volatility because of a series of backlashes to the discovery of widespread corruption and inefficiencies linked to large investments in infrastructure programs.

During good economic situations, this scenario is characterized by sufficient economic performance to fund government initiatives in energy. Overall economic growth is more moderate than in Freeway and is still distributed unevenly across regions. In a bad economic situation, there is sufficient economic performance in shielded developing countries (for example, China and Brazil), while growth weakens in developed nations. As spending has been heavily dependent on governments, the public sector accumulates large debt levels. The effect of a downward cycle is partially mitigated by lower energy demand and import bills, due to gains in energy efficiency. Wealth disparity is less obvious in industrial countries, while the wealth level of African nations improves slightly due to technology transfers (e.g., Copenhagen Accord), and multi-lateral programs (e.g., UNIDO access to energy programs). Corruption is highest in South Asia, sub-Saharan Africa, and transition economies. Bureaucracy remains an issue in most regions, while tax regulations severely constrain OECD and post-socialist transition economies. Subsidies have increased for green goods and services.

In the energy upstream sector, few new areas for exploration and production have been opened leading to tight supplies and higher energy prices at the beginning of the scenario period, but lower and more stable prices after a rapid transition to renewable energy sources. Electricity prices increase sharply, leading to more energy poverty and requiring immediate government subsidies for low-income citizens. Security of supply and climate-change concerns demand reduced dependence on fossil fuels. Large government programs focus on energy efficiency and energy-saving programs. This results in more effective energy efficiency and energy saving, and a drop in the global demand for energy in this scenario.

In contrast with Freeway, this scenario has a stronger emphasis on public transportation, and solutions are more long term with a wider perspective. Shipping, aviation, rail, and trucking have lower growth rates, because of lower economic growth. However, HSR networks penetrate on a larger scale, especially in the second half of the scenario period. Car-ownerships rates are lower as people rely more on public transportation systems. Improvements in high efficiency ICEs continue and hybrid cars penetrate the market more moderately. Driven by government directives and subject to significant improvement to the grid systems, EVs and large-scale use of electricity in public transportation fleets penetrate the market more quickly. Local governments with access to domestic gas reserves adopt significant numbers of CNG vehicles. FCVs are also adopted, but on a small scale just so as to reduce dependency on foreign oil. In this scenario, first-generation biofuels make an increasing contribution to the fuel mix but with larger impact on food prices.

6. Regional Considerations

In addition to the information material collected by network members on critical drivers and constraints, some regional inputs were also gathered in workshops conducted in Johannesburg, Bangkok, Thessaloniki, London, Rio de Janeiro, and Washington DC. This section briefly presents some of these major inputs that could shape the future of transport in these various regions. A complete description and more detailed regional inputs for the two scenarios are included in Appendix A.

6.1 Africa and the Middle East

We have seen from the earlier discussion on economic growth that between 1990 and 2008, Africa's GDP grew at about 3.8% per year, while that of the Middle East grew at 3.9% per year (both were higher than the global average of 3.3%). Through 2035, Africa's GDP is expected to grow at about 3.5% per year, while the Middle East is expected to grow at 3.9% per year (both higher than the global average of 3.2%). As for wealth and GDP levels, the region experiences an outpouring of civil unrest due to income disparity and increasing crime waves, especially in Africa. Sub-Saharan Africa has the lowest GDP per capita in the world ($1,138 versus a world average of $8,599), but is expected to slowly improve towards the backend of the scenario period. The North African nations have a relatively higher per capita GDP of close to $3,000, although this is still far below the world's average. The GDP of the Middle Eastern nations are higher than most African countries, standing at an average of $5,763. Problems with frustrated young and poor portions of the population are slightly alleviated due to improving unemployment numbers, but still unemployment is a challenging factor throughout the scenario period.

Looking at the challenging population and demographic statistics, we can also see that sub-Saharan Africa has the world's highest population growth rate of 2.5%, relative to the global growth rate of 1.2 %, while the Middle East and North Africa (MENA) region has a growth rate of 1.9% per year. Through 2035, Africa's population is expected to grow at about 1.9% and that of the Middle East is expected to grow at 1.5% (both higher than the global average of 0.9%). This means that Africa is expected to double by 2050. In sub-Saharan Africa, almost 43% of the population is 14 years of age or under, while in MENA the share is about 31% (compared with the world's average of 27.2%).

In terms of geopolitics, the demographic demands in a few West African and MENA energy-rich countries (i.e., Nigeria, Libya, Iraq, and Iran) are having an impact on their political and social stabilities, and their ability to export oil. Additionally, these countries are most likely to be politically unstable though 2050, putting critical hydrocarbon supplies from MENA at risk. Unfortunately, the straits of Hormuz, Bab Al-Mandab, and the Suez Canal remain vulnerable. Conflicts and instabilities in Libya, Sudan, Somalia, West Africa, Iraq, Iran, Lebanon, Palestine, and Yemen are expected to last for a few more decades. The Arab Spring in MENA is expected to end at Libya, Yemen, and Syria, but ensuing political reforms will take years. Unfortunately, these conflicts are expected to slow down the demand for transportation in these countries.

The lack of proper government frameworks remains a challenge for market privatization, liberalization, and deregulation in both Africa and the Middle East (South Africa could be the exception). Fortunately, there is no lack of credit and willing investors for energy infrastructure investment, but corruption is still a concern in most countries (with the exception of high-income Middle Eastern countries). Sub-Saharan Africa is the least bureaucratic in the world. Bureaucracy in the MENA region remains high. The region's tax regulations remain at about the global average. Subsidies in West Africa and MENA countries remain heavily dependent on subsidies, especially subsidies related to energy resources.

With regard to infrastructure, the region's overall demand for road transport is expected to match the increase in the number of roads being built over the next decades. Investments in road-building programs are expected to be massive. Investment in energy infrastructure remains urgent, and access to energy remains a top priority. Multilateral sponsorship programs improve government regulation, and increase private sector investments into public sector. The divide between rural and urban transport options increases as a result of increased investments in urban infrastructure. In addition, the accessibility of some rural areas improves due to road-construction programs.

Only about 36% of sub-Saharan Africans live in cities, compared with around 60% in MENA (the global average is about 50%). Good economies will invite better planning and problem solving. Increasingly, young MENA people are migrating to the major cities looking for employment, adding more stress on urban infrastructure (housing, infrastructure, and transportation). This is being met by very little public planning, and urbanization is growing faster than the government is responding. Extreme congestion and pollution problems experienced in the major urban centres are increasing.

As for consumer behaviour and lifestyle, the regions individuals' interest remains at front. Consumers in sub-Saharan Africa are still looking for any affordable transport means. In the higher income and more urbanized MENA, population is frustrated with congestion and pollution problems, mainly in major cities.

The region's individual transport solutions are expected to remain dominant. Electrification of public transport systems (rail, trams, and buses) is possible at a later stage in higher-income nations (e.g., South Africa, Nigeria, and Namibia). In 2005, Africa had one of the lowest levels of private car-ownership in the world, with only 20 privately owned cars per 1,000 people. For the Middle East, the level is relatively higher (80 cars per 1,000 people). Private car-ownership is something that many young Africans and Middle Easterners would like to have, particularly in the absence of reliable, affordable, and convenient mass-transit and public-transportation options.

In 2005, the passenger LDV stock was about 15 million vehicles in Africa and about 15 million vehicles in the Middle East. In the same year, new car sales in Africa were about 1.6 million per year and about the same in the Middle East. There is a large market for second-hand automobiles, mainly from second-hand cars imported from the EU. There were about 243,000 used cars flowing into Africa in 2005 (mostly from the EU) and about 391,000 into the Middle East (mostly from the US, followed by Japan). Conventional gasoline and diesel ICEs dominate existing stocks of both new and used sales. The ICE is expected to continue to dominate through 2050. The potential for hybrids, EVs, CNGVs, FCVs and even HSRs is expected to remain at minimum level.

As for air traffic and freight, the region is expected to have high growth for both passenger travel and freight, at 5–6% per year over the next 20 years. Africa's passenger fleet is expected to double from 660 planes to 1,130 planes, and the Middle East to more than double from 950 to 2440 planes. Africa is expected to have a growth rate of about 5.5% for passenger travel, and 6% for cargo per year through 2029. The Middle East is expected to have a growth rate of 7.1% for passenger and a 6.8% for cargo per year through 2029.

Fortunately, these developments in the region's transportation and transport are expected to benefit from the fact that most of the region's countries have energy reserves or access to them, which will help fuel the higher level of motorization expected through 2050. Currently, the region's transportation sector mostly uses conventional gasoline and diesel. Individual transport is likely to remain largely based on gasoline and diesel for decades to come. In 2008, Africa consumed 28 mtoe (about 0.564 million barrels per day) of gasoline and about 38 mtoe (about 0.765 million barrels per day) of diesel. Similarly, the Middle East consumed 46 mtoe (about 0.939 million barrels per day) of gasoline and about 54 mtoe (about 1,082 million barrels per day) of diesel. By 2050, consumption is expected to double for Africa (from about 100 mtoe to 200 mtoe) and triple for the Middle East (from about 100 to 300 mote), again mostly in gasoline and diesel. As for the non-conventional fuels, first-generation biofuels have a potential in areas where they do not threaten food security (e.g., ethanol production in Swaziland).

Regarding climate change, neither Africa nor the Middle East is going green. Currently, the trend is that local strategies are aimed at providing maximum energy at the lowest cost possible. Additional funding for energy-efficiency programs and climate-change mitigation initiatives will depend on foreign-funding mechanisms. There is consensus that a consolidated approach promoting all forms of energy is the best way forward.

6.2 Asia

Between 1990 and 2008, Asia's GDP grew at about 7.4% per year, almost double the global average of 3.3%. This enormous growth was driven by China growing at 10% a year and India at 5.7%. Through 2035, the Asian Development Bank (ADB) expects growth in Asia to be driven by the economies of China, India, Indonesia, Japan, Republic of Korea, Thailand, and Malaysia. Asia's GDP is expected to grow at about 5.4% per year, which is still higher than the global average of 3.2%. Again, the growth engines are China, growing at 5.7% and India, growing at 6.4% per year. The Japanese economy, which has been growing at about 1.2% for the last 20 years (on average), is expected to grow at about 1% per year through 2035. Evidently, Japanese output has suffered after Fukushima and its growth is expected to be crippled by its national debt problems. Currently, Japan's net debt stands at 128% of its GDP (higher than Greece, which is at 124%). As for the GDP per capita levels, we can categorize the Asian countries according to certain economic development stages. The GDP per capita is high for OECD members (i.e., Korea's is $17,078 and Japan's is $39,738) and low for others (i.e., China's is $3,744 and India's is $1,192).

As for population, Asia currently has 60% of the world's population (4.1 out of 6.8 billion), with China being the most populous country today at 1.3 billion people, followed by India at 1.189 billion. Asia's population growth is about 0.7% a year (China is 0.5% and India is about 1.3%), which is lower than the global rate of 1.2%. Through 2035, Asia's population is expected to grow almost at the global average (0.8% compared with a global average of 0.9%). China will grow at 0.3%, while India will grow at 1%. Most of the growth will come from South Asia, with India exceeding China's population by 2030. Currently, almost 22% of Asia's population is 14 years or under (compared with the world average of 27%). South Asia is the youngest region (in both India and China 31% of the population is below 14 years,). Looking at future trends, Japan and China's populations are aging and declining, while the populations of India, Pakistan, Bangladesh, and Indonesia are growing, with increasing numbers of younger people. Primarily, Chinese demographic change is due to its one-child policy, the results of will kick in during this decade. The share of Chinese under age 15 dropped 6.3%, while that of those over 60 rose by 2.93%. This represents a shrinking labour market. Demographic decline will become a serious concern in Japan. The United Nations estimates that 36.5% of the Japanese population will be aged 65 or more by 2050.

Along with these changes in levels of economic growth and population, there will also be some political challenges. The Chinese political system is scheduled to go through a power transfer in 2012. The old ruling elite will step down and give way to a newer generation. The focus will be on maintaining a steady level of economic growth along with social stability. Indicators of social unrest will be watched very closely by the government. Militarily, China will be seeking to exert its influence in the Asian region more strongly. Stability will hinge on achieving minimum economic growth of about 9%. Instability in the Korean peninsula will last for a few more decades. The threat of nuclear war between India and Pakistan will continue for many years, until the Kashmir problem is solved.

With regard to government frameworks, government regulation remains high in China. Big infrastructure programs keep large sectors of the population employed and political reforms stay on the back-burner. In contrast, India has a more liberal regulation policy, but the size of its bureaucracy limits its growth potential. Since India liberalized in 1991, it has experienced an average annual GDP growth rate of 4.8%. The Chinese growth rate over the same period has been 9%. Fortunately, foreign investment continues to flow strongly into Asian economies. In fact, the region's FDI levels were up 43% since last year, with 21% of foreign equity attracted by the services sector. In contrast, India continues to lag. India's total FDI inflow between 2000 and 2011 was $19billion. Over the same period, the FDI in China for 2010 was $105.7 billion. The biggest sector for FDI in India was services, while in China, Thailand, and Taiwan it was manufacturing.

Corruption in Asia remains a challenge (South Asia is the most corrupt worldwide). It continues to plague the Indian government at the national and state levels: India is ranked 87 in the latest Transparency International Corruption Rankings with a score of 3.3 (highly corrupt). China has a policy of harshly punishing its offenders. However, allegations of corruption against state officials continue. The Chinese government has so far not tolerated any strong widespread challenge and has regularly imprisoned its harshest critics. Bureaucracy remains very strong in Asia, especially in India and China. All major external investors have to deal with a major bureaucratic element. This causes delays and higher project costs, especially in India. Regarding tax regulation, India has an effective statutory corporate tax rate of 30%–40% while China has an effective statutory corporate tax rate of 25%, down from 30% in 2007. The overall tax regulations in Asia are considered low compared with OECD countries. Fuel and electricity remain heavily subsidized in most Asian countries. Any cost increase at the pumps will have an immediate adverse impact on economic growth. The Chinese government still subsidizes electricity and regularly subsidizes state-owned enterprises.

While most of the manufacturing in the region is done in China, Korea, and Japan, the R&D for high-end electronics is carried out in countries like Germany, Japan, US, etc. India has a number of R&D centres for software, pharmaceuticals, and other industries and starts to outpace China in terms of technology development. Luckily, regional competition is increasing. Asia as a whole (with the exception of Japan and Korea) remains dependent on technology transfer.

In addition to the above challenges facing Asian governments, there will also be a few critical challenges relating to urban planning. In 2000, around 48% of the Asian populations lived in cities, around 30% of the Indian population lived in urban centres, while in China it was around 44%. These rates are set to increase. The rural-to-urban influx is also increasing in China and India. Internal migration is also rising. In China, in the Bohai Economic Rim, a series of urban centres located in the industrial hinterland surrounding Beijing and Tianjin is also being developed. These changes are expected to strain public transportation systems. The Asian public-road transport system may shift from diesel to CNG to reduce urban air pollution. In India, intra-city rail networks are being planned to reduce road congestion. India also plans to further electrify its rail system in the coming decades. At the same time, China has embarked on an ambitious high-speed rail (HSR) network to reduce intercity commuting time. However, safety and quality concerns remain as work progresses at a fast pace under local contractors who are likely to cut corners. Currently, China leads the world's HSRs with 4,840 km in operation and 15,478 km under construction. It is planning more than 12,000 km by 2020, and recent HSR accidents may not slow down these plans. Japan has a total of 2,495 km of HSRs, Taiwan has 345 km, while South Korea has about 412 km.

As incomes rise, there will be a shift towards a demand for transport. In 2005, vehicle ownership was about 11 cars per 1,000 capita in China and about 6 cars per capita in India, compared with a global average of 111 cars per 1,000 capita. Recently, car ownership rate in China has been growing at a rate of 12% per year, while in India it has been growing at 9% per year. The demand growth extends also to the two-three wheelers. In fact, Asia produces 95% of global two-three wheelers, which constitutes 75% of the stocks in the world. China is the fastest growing two-three wheelers market but is still within 50–100 per 1,000 capita (and this is below Malaysia and Thailand which have 250 per 1,000 capita). China's ban on using gasoline motorcycles and scooters in Beijing and Shanghai has promoted the use of E-bikes. Currently, about 100 million E-bikes are in circulation in China and the sales are about 20 million per year.

In 2005, the passenger LDV stock was about 14 million vehicles in China, 7 million in India, and 26 million in other parts of Asia. New car sales in 2005 were about 3.1 million in China, 1.1 million in India, and 2.9 in other Asia. The flow of used cars to Asia in the same year was about 274,000 cars, mostly from Japan. Indeed, conventional ICEs dominate the car stocks and ICE dominance is expected to last through 2050. Diesel ICEs constituted about 25% of India's LDV stocks in 2005, and are still gaining popularity. This is due to the low cost of diesel at the pump compared with petrol. Increasing fuel efficiency, combined with turbocharged technology, has also boosted the demand for diesel vehicles in India. Gasoline ICEs are greatly in demand in China and this demand will continue to grow. Hybrid penetration in the Asian LDV market is low. The only exception could be the Japanese market, which had sales of about 334,000 units in 2009 and 500,000 units in 2010. Hybrids are expected to increase market share in high-income countries (Japan and Korea). The IEA forecasts that globally there will be about 15–20 million hybrids by 2020 and about 80 million by 2040.

The primary Asian markets taking up EVs are expected to be China, Japan, and Korea (together accounting for 75% of EV purchases in the Asian market). EV penetration is more likely in China than India, due to the Chinese manufacturing strength and local production of rare earths like lithium, essential for the production of batteries and electric vehicles in general. By 2050, EVs are expected to remain a small fraction of the fleet (less than 5%). For CNGVs, governments are expected to put CNG infrastructure programs in place, as part of the drive to reduce dependency on imported oil, and with air quality considerations in mind. In fact, CNG vehicles are becoming increasingly popular in the Asian market due to their low cost of CNG per km compared with other fuels. In 2009, Asia is estimated to have 11.4 million vehicles, with about 72% located in Pakistan, Argentina, Brazil, Iran, and India. However, CNGVs will still constitute a small fraction of the total stock. FCVs are expected to stay at minimum level and potential. An increase in fuel efficiency will have to become a main feature of the Asian automobile market over the scenario period.

Asian air traffic will also increase, largely due to an increase in population and economic growth. Over the next 20 years, the overall Asian Pacific freighter fleet is expected to grow five-fold, rising from 16% of global fleet to almost 40%. Similarly, the Asian Pacific passenger fleet is expected to grow three-fold from 4,110 planes to 12,200 planes over the next 20 years. India's freighter fleet alone is expected to grow 13.5 times by 2028. India needs 3,000 additional aircraft over the next decade to maintain economic growth. Chinese investment in air infrastructure over the next 10 years is planned to be US$64 billion (100 new airports). India has earmarked US$7 billion for airport expansion over the next five years.

In Asia, improvements in road penetration and highways will generate much higher traffic and increasing fuel consumption in the future. In China and India, transport fuel consumption is expected to rise to staggering levels, while the region will continue to depend heavily on oil imports and will seek increased cooperation from oil-exporting countries like Saudi Arabia, Iran, UAE, and Russia to service their demand. A move has begun to exploit the resources of the central Asian region.

Consumption levels will increase across most of the developing Asian economies. The transportation sector will mostly use conventional gasoline and diesel. In 2008, China consumed about 1.3 million barrels per day of gasoline and about 1.5 million barrels per day of diesel, OECD-Asia consumed 1.3 million barrels per day of gasoline and about 1.1 million barrels per day of diesel, while the rest of Asia consumed 1.3 million barrels per day of gasoline and about 1.7 million barrels per day of diesel. Between 2000 and 2005, passenger and freight transport were up 26% and 29.2%, respectively, in China. By 2050, China's transport-fuel consumption is expected to increase from 150 mtoe to around 700 mtoe (mostly conventional gasoline, diesel, and jet fuel). Similarly, India's transport-fuel consumption is expected to increase from 50 mtoe to around 400 mtoe (mostly conventional gasoline, diesel, and jet fuel). Moreover, OECD-Pacific transport-fuel consumption is expected to remain at the current level of around 200 mtoe (mostly conventional gasoline, diesel, and jet fuel). Other Asia transport-fuel consumption is expected to increase from 300 mtoe to around 550 mtoe (mostly conventional gasoline, diesel, and jet fuel).

Developing countries in Asia are also expected to consume 16mtoe (322,000 barrel per day) of biofuels in 2030 (China, 7.9 mtoe; India, 2.4 mtoe; Indonesia, 1.5 mtoe). Competitive biofuel production can be achieved in Southeast Asian countries which produce palm oil. In 2008, about 4% of global biofuels were produced in Asia (3 out of 67 billion liters). While competitive biofuel production in Asia can be achieved through the large-scale farming of oil palms in Southeast Asia, this can threaten local agriculture and cause widespread ecological damage through deforestation.

6.3 Europe and Russia

Between 1990 and 2008, the EU grew by 2.2% per year, slightly below the global average of 3.3%, while Russia grew by 0.6% a year. In Europe, the inflation of average consumer prices in 2010 was about 2% while the average unemployment rate was about 9.3%. Growth in the EU zone is expected to slow down because of the debt crises hitting Greece (net debt is 125% of its GDP); Italy (net debt is 101% of its GDP); Belgium (net debt is 80% of its GDP); Portugal (net debt is 75% of its GDP); and Ireland (net debt is 70% of its GDP). It is widely expected that Greece will default on paying its loans and will expose many European banks (mainly French). Austerity measures will also slow down growth in the EU zone. Through 2035, the World Bank expects the EU to grow at 1.6% a year, while Russia grows at 3%. On the GDP per capita levels, the Euro area had a GDP per capita of about $32,772 in 2010, while Russia had about $8,684 per capita.

As for population, Europe's population stood at around 723 million in 2008. The current population growths are about -0.1% per year for Russia and 0.4% per year for the EU. Most of the EU's population growth is in the northern EU (0.6% per year). Germany, Hungary, and the UK experienced negative population growth rate in 2010. Around 15% of the Russian population is below 14 years old, while for the EU it is about 17%. The 2005 data showed that the EU-25 dependency ratio grew by 1.3% per year, and reached 25% over the last decade. Through 2035, Russia's population is expected to grow at 0.4% per year, while the EU's population is expected to grow by 0.2% a year.

With moderate growth in both economic levels and population, these countries remain politically stable. This is despite the fact that financial crises have lent minor instability to Ireland, Portugal, Italy, and Greece. Other instabilities are expected in the northern Spanish Basque province, and in Northern Ireland. In the German Bundestag, the Green Parliamentary Group has come to dominate politics. As for Russia, it continues demonstrating its fears of NATO and suffers instabilities on its southern borders (Chechen Republic).

With regard to government frameworks, regulations occur at the EU level, and EU member states have to adopt them eventually, while Russia is still heavily regulated. The OECD Europe countries have fully liberalized markets, while the non-OECD Europe countries are gradually privatizing non-performing public assets, especially in light of financial crises. Privatization is still an issue in Russia. Throughout the region, there is a wide range of project-financing options. Corruption is at a minimum in the western EU countries, but very high for eastern EU countries and Russia (second to South Asia). Bureaucracy is quite considerable at the EU level. As for tax regulation, the VAT rate at EU levels for energy products is quite low (15% on average). Denmark, Hungary, and Sweden have the highest VAT rates, at 25%. Tax regulations are still a concern in most OECD countries. The energy subsidies in the EU-15 were estimated in 2001 to be about EUR29 billion. About 43% of these subsidies were for solid fuels, 30% for oil and gas, 19% for renewables, and 8% for nuclear. The EU's average annual subsidies for fossil fuels accounted for almost 75% of total EU energy subsidies, with Italy, the Netherlands, and the United Kingdom providing the highest level of support to the oil and gas sector. Subsidies are also significant in Russia.

The region's governments will have critical challenges relating to infrastructure planning. Currently, about 73% of the region's population is urban. The population density for EU is about 119 persons/sq km, while for Russia it is about 9 persons/sq km. The region's transport modal split is quite diverse. In 2008, it was about 45% roads, 11% rails, 4% inland waterways, 3% pipelines, 37% sea, and less than 1% air. To meet its unilateral 20-20-20 commitment (cutting its emissions by at least 20% of 1990 levels by 2020), Europe aims to connect offshore grids in the North Sea to consumption centres in central Europe; roll out smart-grid technologies; diversify the gas southern corridor (bringing gas in from Caspian Basin, Central Asia, and Middle East); expedite the Baltic Energy Market Interconnection Plan (to reinforce the central European pipeline network); and commission the first Electricity Highways by 2020. About 200 billion euros will need to be invested until 2020 to meet these objectives. Moreover, the existing EU-Russia transport infrastructure is old and will be very expensive to replace or modernize. As for HSR, about 24% of the total EU-27 rail network is already HSR, with about 12 HSR lines currently under construction. Unfortunately, Russia is still lagging behind.

The increases in economic growth and population, mainly in non-OECD Europe and Russia, will be associated with an increase in vehicle ownership. In 2005, OECD Europe vehicle ownership stood at 424 cars/1,000 capita while that of Eastern Europe and Russia stood at 149 and 134 cars/1,000 capita, respectively. Through 2050, vehicle ownership for OECD Europe is expected to increase slightly, but will almost double for Russia and non-OECD Europe. In Europe, diesel ICEs are gaining popularity (constituting about 30% of OECD's LDV stocks). In 2005, LDV stocks stood at about 228 million in OECD Europe, 18 million in Eastern Europe, and 29 million in Russia. In the same year, new car sales were about 16 million in OECD Europe, 1.4 million in Eastern Europe, and 2 million in Russia. In addition, about 0.7 million used cars were shipped from Western Europe to eastern Europe, while about 0.3 million cars were shipped from Japan to the FSU in 2005. Conventional ICEVs dominate new sales, used sales, and existing stocks. Through 2050, large efficiency gains are expected in ICEVs due to improvements in fuel and engine efficiencies. For hybrids, Europe had sales of only 110,000 hybrid cars in 2010. In the future, we expect an increase in the share of hybrid vehicles in the region due to improvements in their performances. The IEA forecasts that, globally, there will be about 15–20 million hybrids by 2020, and about 80 million by 2040.

Both FCVs and EVs are expected to remain at minimum levels. The largest market for EVs is expected to be Germany with 25% of the total global EV market, followed by France with 20%, and then the UK and Italy with 15% each. The EV market will initially remain relatively small until breakthroughs in charging and/or battery-storage technologies are achieved post-2020. In some countries, like Germany, Sweden, and Switzerland, governments will introduce incentives and regulations that will ensure the availability of electric public fleets much sooner than in other countries. Regardless of the type of drivetrains, the majority of car sales for EU car manufacturers will shift towards Asia. More CNGVs are expected if gas reserves are accessible.

For freight, the value of EU trade in 2008 (for both export and import) was about EUR 1.4 trillion (EUR 576 billion in air, EUR 476 billion in road, and EUR 46.1 billion in rail). The region has the highest number of commercial freight vehicles in the world (33.97 million in 2008). Through 2029, it is expected that Europe's air freight will increase by 4.4% a year, while its passenger freight will increase by 5% a year. For the Commonwealth of Independent States (CIS), it is expected that the air freight will grow by 4.8% and passenger freight will grow by 5.7% a year. By 2029, the air fleet in Europe is expected to increase from 4,300 to 7,460 airplanes, while in the Commonwealth, it is expected to increase from 1,150 to 1,300 airplanes.

To fuel the transportation sector in Europe, strategies that create links to Central Asia reserves are required. With regard to gas, the EU as a whole will remain heavily dependent on Russian supplies, and is expected to last for a few more decades, especially in light of the current move away from nuclear (e.g., Germany). In 2008, the OECD Europe transportation market was dominated by gasoline, diesel, and jet fuel. It consumed about two million barrels per day of gasoline and about four million barrels per day of diesel. Non-OECD Europe and Russia transportation markets were similarly dominated by gasoline, diesel, and jet fuel. They consumed about 1 million barrels per day of gasoline and about 0.6 million barrels per day of diesel. By 2050, fuel consumptions levels in all countries in OECD Europe, eastern Europe, and Russia are expected to remain almost at current levels. The EU's biofuels production in 2009 was about 0.18 million barrels per day (about 17% of the global), mostly comprising biodiesel (110,000 barrels per day and bioethanol 46,000 barrels per day). In the optimistic 450 scenario, the IEA expects OECD Europe biofuels consumption to be 0.97 million barrels per day () and consumption in non-OECD EU countries to be 0.1 million barrels per day.

6.4 North America

In 2010, the US and Canada together accounted for 40% of the world's GDP, which was about US$37.2 trillion. Historically, the economic growth rates for US and Canada have been about 2.8% year. Through 2035, it is expected that North American GDP growth will be around 2.2%. The US suffers from high gross debt (annual) as a percentage of its GDP, which is expected to continue rising over the next two years. The net debt currently stands at about 75% of its GDP. The current US unemployment rate stands at 9.2% and is expected to fall over the next five years. The GDP per capita for the US is about $45,989, for Canada about $39,599, and for Mexico about $8,143; in comparison, the global average is about $8,599.

Regarding population, the North American population stood at around 447 million in 2008, comprising the US with about 310 million, Mexico with about 110 million and Canada with the remaining 27 million. The current population growth is about 1.3% for Canada, 1% for the US, and 0.9% for Mexico. In terms of demographics, around 17% of the Canadian population is below 14 years old. The share is about 20% for the US, and about 29%for Mexico. Mexico has only 6% of the population above 65 years, while both Canada and the US have about 13%. Through 2035, both the US population and North American population are expected to grow at 0.7%per year. The US Census Bureau projects the US will be world's third most populous nation through 2050 (comprising 423 million), behind India and China.

With this growth in both population and economic performance, the region remains politically stable. The US is increasingly characterized by bipartisan politics, which will lend an element of uncertainty to long-term energy policies.

In terms of regulations, the region's governments will sustain fully liberal markets, encouraging competition, focusing on increasing energy efficiency, and boosting the contribution of renewables. Canada will continue to develop oil sands with international players. In R&D, the region will remain an innovation hub (especially the US), with many activities focused on developing new technologies, especially electric transport. Finance sources in the region are available and expected to remain so in the future, depending on the economic performance of these countries. Corruption remains at minimum levels. Bureaucracy remains at moderate levels. Like the rest of the OECD countries, taxes remain high in most markets. The US Federal subsidies for energy have more than doubled between 1999 and 2007. In 2007, the US government spending on energy subsidies was about $16.6 billion: $4.8 billion for renewables, $2.8 billion for end use, $2.3 billion for refined coal, $2.1 billion for natural gas and petroleum liquids, $1.2 billion for nuclear, $1.2 billion for electricity, $0.9 billion for coal, and $0.9 billion for conservation. In the same year, Canada spent CAD 1.4 billion on oil and gas subsidies alone. The expenditure on oil sands from 1996–2002 was CAD 1.2 billion. With the exception of Mexico, energy infrastructure across the region remains highly sophisticated. Pipelines, especially the gas network in the US, are fully developed. Efforts are focused on linking Canadian oil sands to US ports and refineries via pipelines.

With regard to urban planning, the region is the second-highest urban land area worldwide after Asia, and the second-lowest urban population density after Oceania. The region has a high urbanization rate: about 82% of the population in the US, 77% in Mexico, and 81% Canada live in urban areas. North American cities are quite spread out and consequently urban consumption of fuel is the highest in the world. Around 80% of urban transport is via individual motorized transport, so automobile usage is more than 10,000km/person/year. Intermodal rail traffic in the US has significantly increased over the past two decades.

Increasing electrification of public transport is expected in urban areas, but the developments of high speed railways across state boundaries are more uncertain. Within the next 25 years, the current US administration aims to roll out high-speed rail to over 80% of the American population. It has about $10 billion of grant funding available to do this, and, so far, 59 projects have been allocated $6 billion. Currently, the US have 362 km of HSR and plans for another 900 km. Public support for this initiative will be crucial for success and will depend on the development of gasoline prices over the next decades.

For individual transport, vehicle ownership in 2005 stood at 710 vehicles per 1,000 population in the US (with growth rate of 1.6% per year); 535 for Canada (with growth rate of 1.6% per year); and 142 for Mexico (growth rate of 2.8% per year). ICE technology remains the dominant transport technology in the region, in both new and used cars. The US government has mandated higher energy efficiency of 22.5 miles per gallon (mpg) for cars and 18 mpg for light trucks. LDV stocks in 2005 were at 211 million in the US, 17 million in Canada, and 15 million in Mexico; sales were 14.7 million in US, 1.3 million in Canada, and 1.3 in Mexico. In 2005, about 0.47 million used cars went from the US to Mexico, and about 0.2 million went from the US to Canada. Within the US, there were about 0.5 million used cars sold. The US's Federal government acquisition of hybrids is growing yearly, but is still at a very low level (only 4,853 vehicles in 2010). The demand and market share for hybrids are both rising, but are still low (290,000 units sold in 2010). The total hybrid fleet is now reaching 2 million cars (around 1%–2% of the global stock, of which most are Toyota Prius, followed by Honda Civic). It is expected that there will be about 15 to 20 million hybrids by 2020, and about 80 million by 2040.

The EV's adoption is expected in urban areas, where distance travelled is within the vehicle range. The US is expected to be the second-largest EV market after Asia. For CNGVs, the region's market is still at low levels, compared to its potential. It is possible that CNG engines for heavy- and medium-duty vehicles will be developed, since the US has the world's largest trucking market, and low gas prices are projected due to abundant reserves of unconventional gas. FCVs are still in the development stages: the IEA believes that the likelihood of FCVs emerging as a future low-carbon option is lower than that of switching to EVs. Research on fuel cells is likely to continue in the US under government support programs.

In the US, the largest transportation market, it is estimated that around 45% of goods by value are handled by water, 25% by air, and 24% by land (truck, rail, and pipelines). Between 2007 and 2050, it is expected that shipping activities will increase by 150% to 300%. In addition, it is expected that passenger travel in North America will increase by 3.4% a year, while freight will increase by about 5% a year over the next 20 years. The number of passenger planes is expected to increase from 6,590 to 9,000 airplanes.

To fuel this transportation market, the US is expected to remain dependent on imported oil. US shale plays will continue to be developed in the US, with increasing focus on developing liquid plays. Canada will be developing its oil sands to their full potential. In 2008, the North American transportation market was dominated by gasoline, diesel, and jet fuel. In fact, the region consumed about 9 million barrels per day of gasoline and about 3.4 million barrels per day of diesel. The US alone consumes about 20 million barrels per day of petroleum products with the transportation sector accounting for about 69.7% of total petroleum use (13.3 million barrels per day, 58% gasoline, and 21% diesel). The demand in North America is expected to increase from 700 mtoe in 2005 to around 800 mtoe in 2050. Light trucks account for 31% of energy use, followed by cars and motorcycles at 28%, other trucks 16%, aircraft 9%, and boats and ships 5% (with others covered by the remaining percentage).

In 2009, the US's biofuels consumption was 0.7 million barrels per day, the world's highest, while the production was about 0.585 million barrels per day of bioethanol and about 44,000 barrels per day of biodiesel (about 45% of the global total, mostly comprising bioethanol from maize). By 2035, the IEA expects the US to account for 38% of the global biofuels market. The US is targeting a production level of 1.162 million barrels per day by 2022 (a growth rate of about 5% per year). Current legislation allows for E10 blending and the farmers' lobby remains keen on increasing it to E15. It is expected that biofuels will continue to grow, although there may be increasing opposition to bioethanol subsidies. In 2009, the IEA estimated that support for biofuels will be around US $8.1 billion.

6.5 Latin America and the Caribbean (LAC)

Currently, the GDP per capita for LAC is about $7,260 (about $8,230 for Brazil). The IMF expects growth in the region to be 4.75% in 2011 and 4.25% in 2012. Through 2035, the GDP growth for LAC is expected to be about 3% per year (about 3.3% for Brazil). Growth will be commodity-based and driven by demand from China.

In 2008, the LAC population stood at 468 million (42%, or 194 million, of which is in Brazil). The region's population growth was about 1.1% a year (0.9% for Brazil) and has been decreasing since the 1990s. About 28% of the total population is under 14 years (26% in Brazil). Through 2035, LAC is expected to grow by 0.8% a year (Brazil at 0.5%).

The region has been undergoing political turmoil, except for Brazil, which has undergone a presidency change and is now stable. Venezuela continues to face uncertainty under Chavez, especially with his failing health. The overall political stability in the region ranges from medium to volatile.

As for governments, most energy companies are government-owned and run, or at least the government is the majority shareholder. The region began liberalizing its trade practices between 1980 and 1990, and active trading is taking place within the region with ALADI, CARICOM, etc. R&D levels remain low and dependent on technology transfers from developed the more countries. Brazil started taking a role on par with western companies in the biofuels sector, in which a large number of international cooperation agreements are signed. Chile, Mexico, Argentina, and Uruguay have consumption levels that are above world average. Finance and funding are quite limited. Funding is limited to infrastructure projects from China, and international organisations like the World Bank and

International Finance Corporation. Chinese funding for infrastructure projects in energy and commodities is currently estimated at around US$ 4 billion per year. Corruption and bureaucracy remain at high levels. Tax regulations are about average. On subsidies, Venezuela holds the world's seventh highest fossil-fuel consumption subsidy (mostly in oil), estimated at around $12 billion in 2009. Mexico also has fuel subsidies, but these are very low in comparison.

The region also spends around 2% of its GDP per year on infrastructure and will need to spend about 4–6% per year to sustain growth. Brazil and Chile have invested heavily in developing their fossil and mineral resources. Across the region, government provides most investment in infrastructure. The region has high levels of urbanization (78% for LAC and 86% for Brazil) and has three megacities in the top 25 megacities worldwide (Sao Paulo, Buenos Aires, and Rio de Janeiro). Of these, Rio is the fastest growing at 0.66% per year. Currently, HSR is not yet under consideration and the railways are undergoing privatization. The region is considered a global leader in BSRs. The first system built was in Curitiba, Brazil, other examples now include Bogota, Sao Paulo, Guayaquil, etc.

The average ownership rate is about 78 cars per 1,000 capita. In Argentina, car ownership is about 186 vehicles per 1,000 population (avg. AGR: 3.1%); in Brazil about 121 vehicles per 1,000 population (avg. AGR: 4.6%); and in Chile 144 vehicles per 1,000 population (avg. AGR: 5.4%). ICEVs are and will continue to remain dominant in the region. Engines in Brazil are Flex Fuel Vehicles (FFVs). In fact, the FFVs in Brazil account for 40% of the car fleet. This is incentivized by government policies towards biofuels. The Latin American region have the highest number of FFVs globally due to widespread blending of ethanol in gasoline. Hybrids, EVs, CNGVs, and FCVs are at minimum levels and potential. Brazil, Chile, Peru, Argentina, and Bolivia are all set to experience economic and transport growth in the coming decades due to mineral wealth exploitation.

To fuel its transportation sector, Brazil has embarked on developing its sub-salt oil reserves. Ultra-deep water drilling has changed the oil picture. Development of Venezuela's hydrocarbon reserves has slowed during the Chavez regime. The region also has significant reserves of conventional gas in Venezuela, Bolivia, Argentina, Mexico, and Trinidad and Tobago. In general, the region is still heavily dependent on conventional gasoline, diesel, and jet fuel and is expected to remain dependent on these fuels through 2050. In 2008, LAC consumed about 47 mtoe (about 939,000 barrels per day) of gasoline and 62 mtoe (about 1.236 million barrels per day) of diesel. The region's fuel consumption is expected to double between 2005 and 2050, from 150 mtoe to reach around 300 mtoe. Regarding biofuels, Brazil is the second-largest biofuel producer (after the US) with a production level of 27% of the global total, mostly comprising bioethanol from sugar cane (0.467 million barrels per day) and around 19,000 barrels per day of biodiesel. Consumption of biofuels in the region in 2009 was 0.35 million barrels per day, with Brazil's consumption alone accounting for 0.31 million barrels per day. The balance was exported (mainly to the EU and US). These large increases in biofuel cultivation are likely to put increasing pressure on sugar crops, land and water resources, and will eventually reach natural resource limits.

On aviation and hauling, the main mode of transport is road. Most of the haulage is carried via medium trucks. As for aviation, it is expected that the number of aircraft in the region in 2029 will be 2,770, up from today's level of 1,130. Through 2029, air cargo traffic is expected to increase by 6.9% a year, and the passenger traffic by 6.7% a year.

7. Modelling and Quantification

To quantify the two scenarios, the study group put together the information gathered on the critical drivers and uncertainties with the regional inputs gathered throughout the regional workshops. This section gives a brief description of the Paul Scherrer Institute's (PSI) transport model, and then presents and compares results for the two scenarios in greater detail.

7.1 Model Overview

The scenarios were quantified using a submodule of the Global Multi-Regional MARKAL (GMM) energy system model. GMM is a technologically detailed, cost-minimization model (bottom-up) developed and maintained by the Energy Economics Group at the PSI, Switzerland. The model determines the least-cost combination of technologies and fuels to satisfy demands and fulfil other constraints, from the perspective of a single social planner. Some non-cost decisions, like behavioural aspects of technology and fuel choice, are taken into account by additional constraints and appropriate cost assumptions. Future expenditures are discounted to account for time preferences and cost of capital.

The enhanced submodule for the transport sector has a global scope, encompassing 15 world regions (Figure 13), including the US, Canada, Mexico, Brazil, China, India, Russia, Africa, the former Soviet Union (excluding Russia), OECD Europe, eastern Europe, OECD Pacific, other Latin

Figure 13

The 15 world regions of the transport model

Source: Paul Scherer Institute

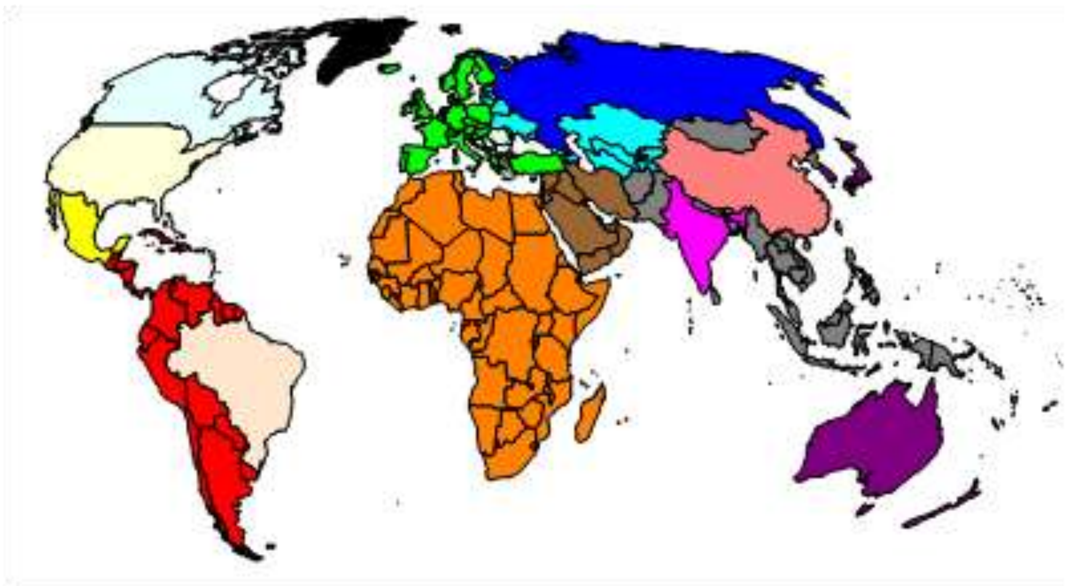


Table 8
Input parameter (exogenous variables)

	Input parameter (exogenous variables)	Unit/Level
General	Base year	2005
	Time horizon	2050
	Time step	5 year
	LDV Technology lifetime	15 years
	Discount rate	5%
	Annual GDP growth rate	%
	Population	million
LDV	Motorization rate	car/1,000 capita
	Share of LDV types (base year 2005)	million
	LDV mileage	1000 v-km/y/car
	LDV transport demand	billion v-km/y
	LDV efficiency	MJ/km
	LDV efficiency targets	gCO_2/km
	Share of short-range cars	10 % (v-km/y)
	LDV size of batteries and FCV	kWh and kW / car
	Fixed O&M cost	$(2000)/car/y
	LDV investment cost	$(2000)/car/y
	Investing costs for battery and FCV	$(2000)/kWh
	Investment cost adjustments	%
	MeOH & EtOH blend	% (J)
Other surface transports	Other surface transport demand	PJ
	Share of fuelling options (base year 2005)	PJ
	Aggregated efficiency	J(in)/J(out)
	Aggregated cost	$(2000)/J
	MeOH & EtOH % blend	% (J)
Aviation	Aviation transport demand	PJ
	Aggregated efficiency	J(in)/J(out)
	Aggregated cost	$(2000)/J
	Blend of biodiesel in aviation fuel	% (J)
Fuels	Share of fuels (base year 2005)	% (J)
	CO_2-emission of fuels	gC/J
	CO_2-taxes	$(2000)/gC
	Biofuel targets	J or %(J)
	Fuel cost	$(2000)/J

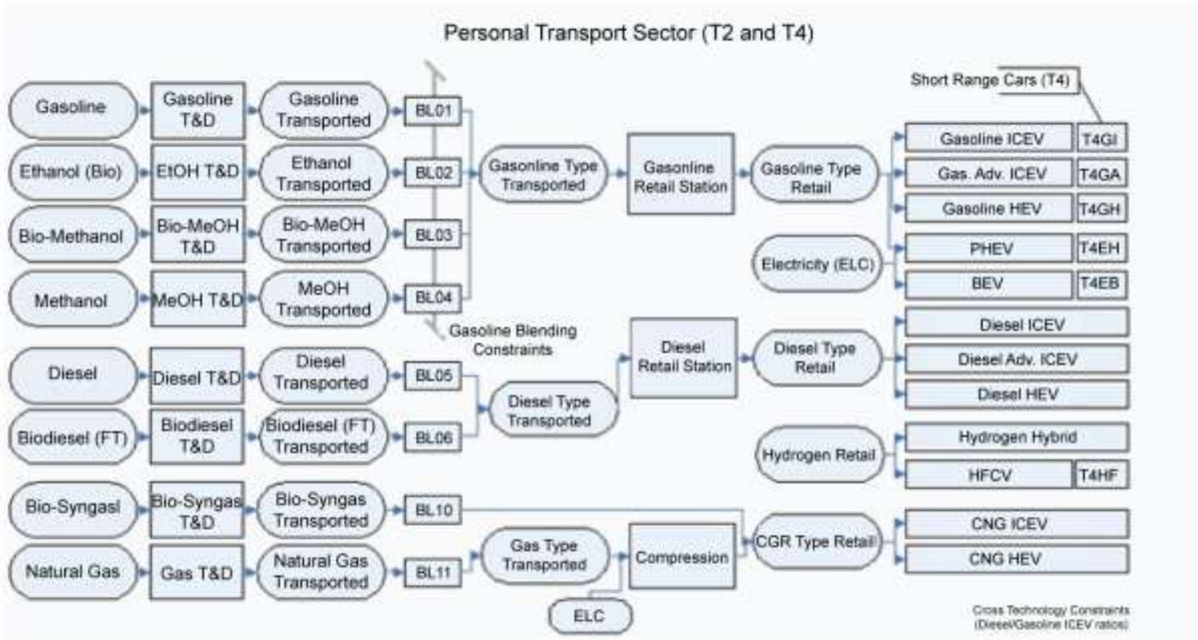
America and the Caribbean (excluding Brazil and Mexico), other Asia (excluding India and China), and the Middle East. For each region, specific scenario assumptions are applied to the dynamics of technology characteristics, transport demands, and other factors. Regional and technology differentiation leads to a large-scale optimization model with approximately 40,000 equations and 30,000 variables.

The transport model is calibrated to technology activity and capacity statistics for the year 2005. The calibration includes current demands for each subsector, currently available fuelling options, and technology and fuel shares, as well as estimates on current costs of fuels and of technologies. The reported model horizon is year 2050, with a step length of five years. To ensure a better representation of the year 2010 for this report, the

Figure 14

Personal transport sector in GMM

Source: Paul Scherrer Institute



model uses additional statistics for recent years in cases where reliable data are available. Current legislation and highly probable short-term implemented policies are included as constraints on the model, e.g., regional mandates for the improvement of personal car efficiency and for the use of different types of biofuels.

In GMM submodule, the transport sector is divided into three subsectors, including personal car transport (LDV), other surface transport (trucks, buses, trains, ships, etc.), and aviation. The model's input parameter assumptions relating to these three subsectors are summarized in Table 8 and the full numeric values of these input parameters are included in Appendix B.

The demand projections for each transport subsector were derived from economic and population scenarios. The personal car transport sector is modelled with a high level of detail (Figure14). All of today's relevant car technologies are represented, along with emerging vehicle technologies. The largest category is the ICEV, which uses gasoline-type fuel. This category also includes ICEVs that accept ethanol and similar fuels in a fixed or flexible blending ratio (because the engines are assumed to require only minor modifications) and FFVs. Other categories include the diesel-type ICEV, the gas-fuelled ICEV, and the hybrid electric vehicles (HEVs), where the hybridization is modelled separately for diesel and gasoline-type ICEVs. Other technology options include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), hydrogen hybrid ICEVs, and hydrogen fuel cell vehicles with hybridization (HFCVs). The transport model also includes a short-range car category with a limited driving range and reduced cost assumptions.

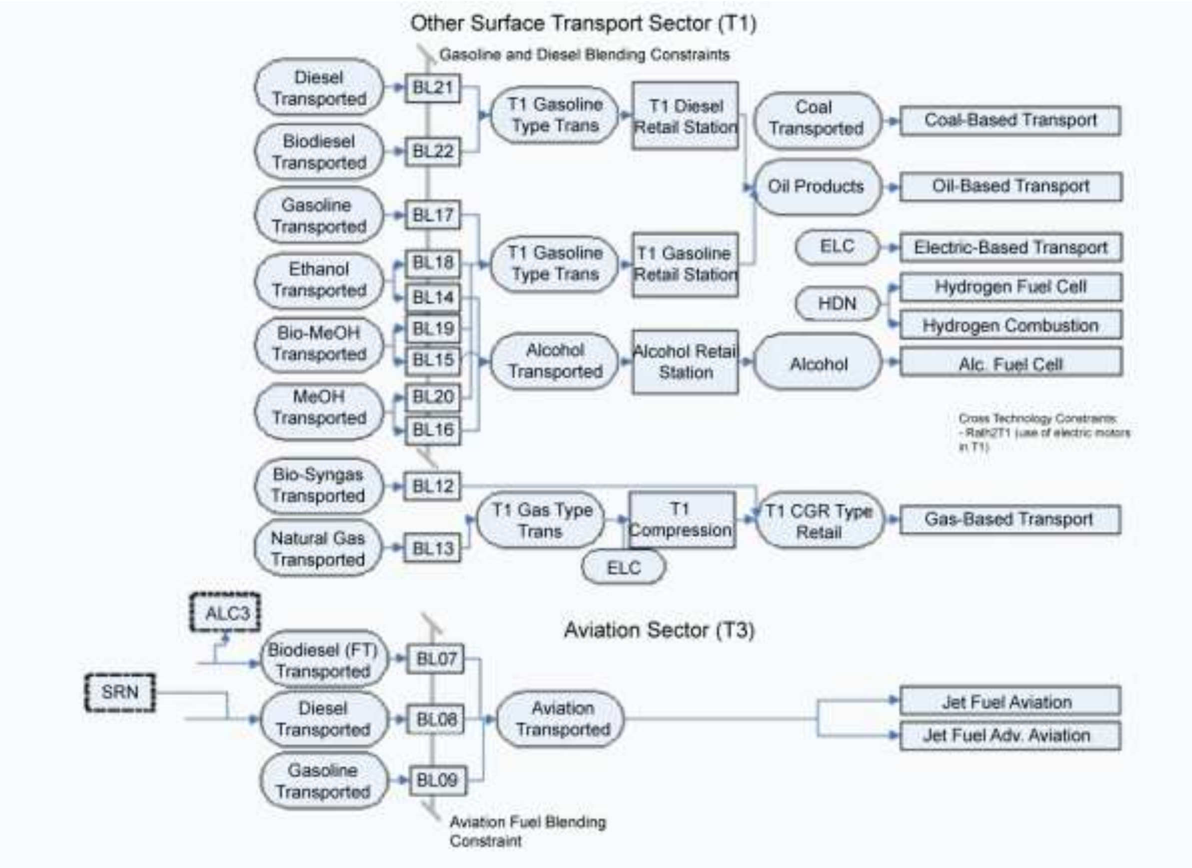
The fuelling options of the cars include fossil fuels like gasoline, diesel, natural gas, and methanol derived from coal (in limited blending ratio). Different types of biofuels can be blended into the aforementioned fuels. Alternative fuels, comprising electricity and hydrogen, have different dynamics in each region for their carbon content (well-to-tank) according to scenario assumptions. Biofuels are also assumed to have a small well-to-tank carbon content. Hence, in scenarios assumed to include climate policy, all alternative fuels are potentially affected.

The other surface transport and aviation sectors are mainly categorized by available fuelling options and associated energy-efficiency factors for useful energy services (Figure 15). In aviation, current technology options are represented, along with a more advanced technology with increased efficiency and higher Operations and Maintenance

Figure 15

Other surface transport and aviation sectors in GMM

Source: Paul Scherrer Institute



(O&M) costs (excluding fuel costs), while fuelling options include conventional kerosene, and synthetic biomass- and coal-to-liquids fuels.

The statistics for calibrating the transport model and the data for the parameter assumptions are from various sources. Many data sets were taken from the full GMM energy model, while some others were taken from sources including IEA, Oak Ridge National Laboratory's Transportation Energy Data book, the Annual Energy Outlook from the US Department of Energy, hybrid-car sale statistics from car manufacturers, and statistics from the International Gas Union, the International Road Federation, and the International Council on Clean Transportation.

The calibrated model solves for the minimum cost-optimal allocation for the global transport sector. As Table 9 shows, the model's output variables include fuel demand, technology shares, and emissions from the three main sectors of the model, namely LDVs, other surface transport, and aviation.

Table 9

Output (endogenous variables)

Model output (endogenous variables)	Unit
Fuel demand for cars	J
Fuel demand for other surface transport	J
Fuel demand for aviation	J
LDV technology share	v-km/y
Other surface transport shares	J
Aviation technology share	J
CO_2 emissions	gC
CO_2 emissions from cars	gC

7.2 Modelling Results

In this section, we briefly present and discuss the results for the two scenarios with regard to (1) fuel demands for LDV cars, other surface transport, and aviation, and for overall transport; (2) the number of cars in circulation; and (3) CO_2 emissions from cars and from the overall transport sector. We also compare the results for the two scenarios. The full detailed modelling results are included in Appendix C.

7.3 Results for Freeway

Fuel Demand

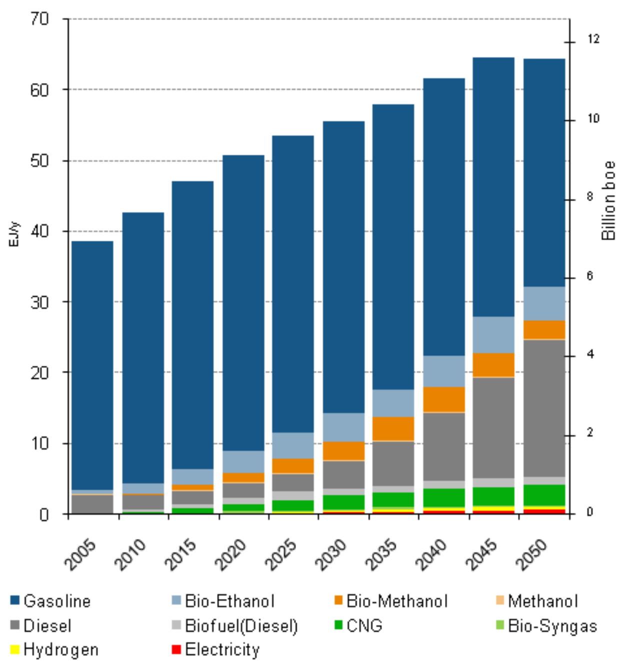
In Freeway, global fuel consumption for cars is expected to increase by about 51% between 2010 and 2050 (Figure 16a). The world's car fleet will still depend heavily on gasoline and diesel, which will still constitute about 80% of the fuel mix in 2050. Biofuels will constitute around 12%, while CNG will provide about 5%. Comparing the demand pattern between 2010 and 2050, we can note that the bulk of the demand will be in the non-OECD countries (increasing from 26% to 63%) rather than OECD countries, and that the demand will still be dominated by gasoline and diesel (Figure 16b).

Looking at global fuel consumption for the other surface transport and aviation, the results show that the fuel demand in 2050 will be double the 2010 level (Figure17a). Again, the world will still depend on fossil fuels, within which diesel, fuel oil and jet fuel will constitute around 94%, and most of the

Figure 16

Fuels for LDV cars

(a) Demand between 2010 and 2050



(b) Demand of OECD vs. non-OECD (EJ)

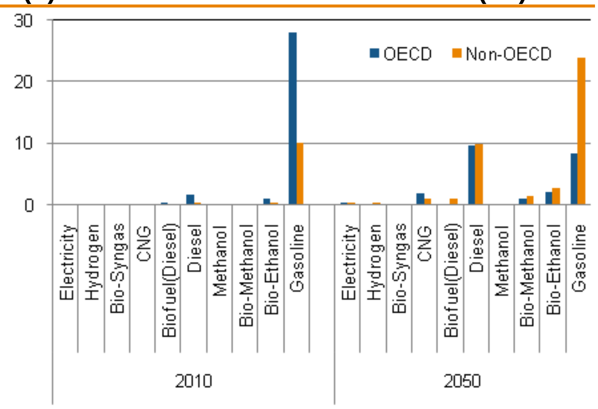
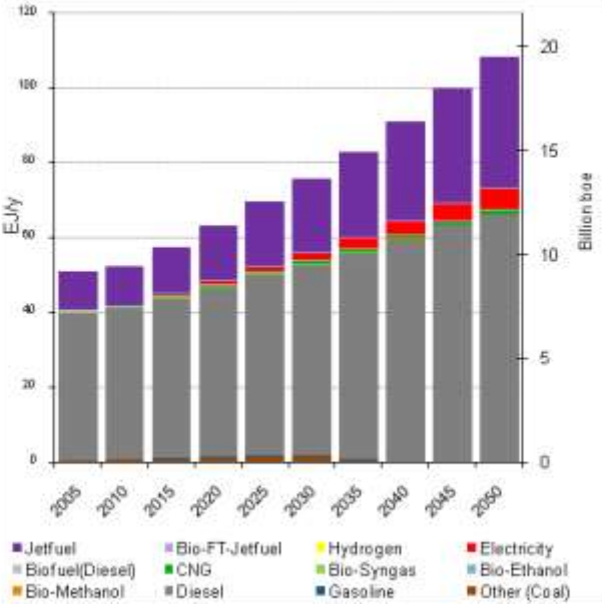


Figure 17

Fuel in other surface transport and aviation

(a) Demand between 2010 and 2050



(b) Demand of OECD vs. non-OECD (EJ)

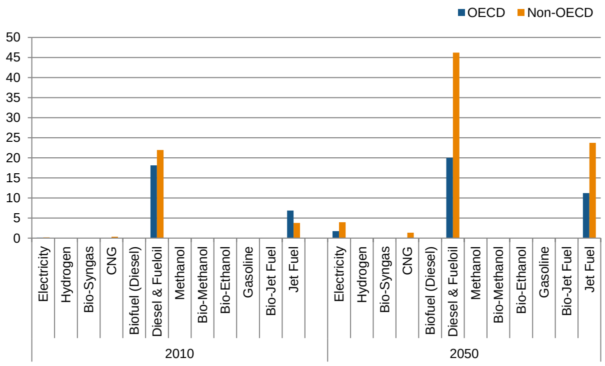
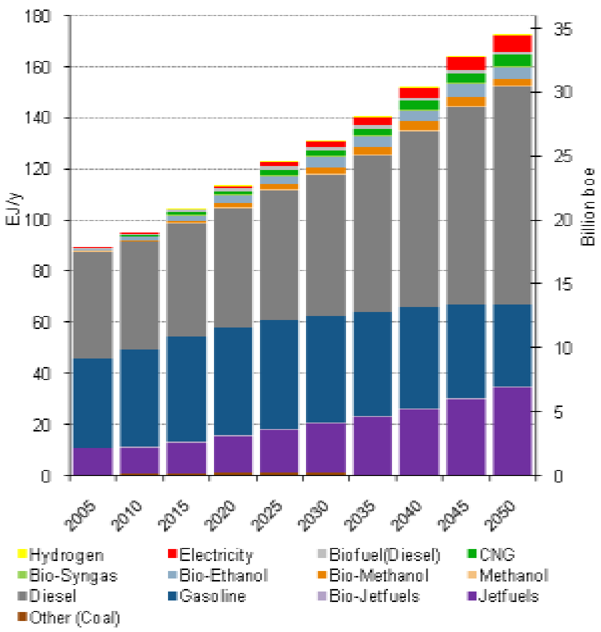


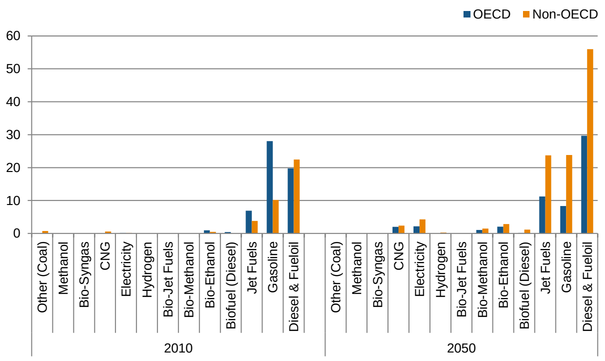
Figure 18

Fuels in all transport

(a) Demand between 2010 and 2050



(b) Demand of OECD vs. non-OECD (EJ)

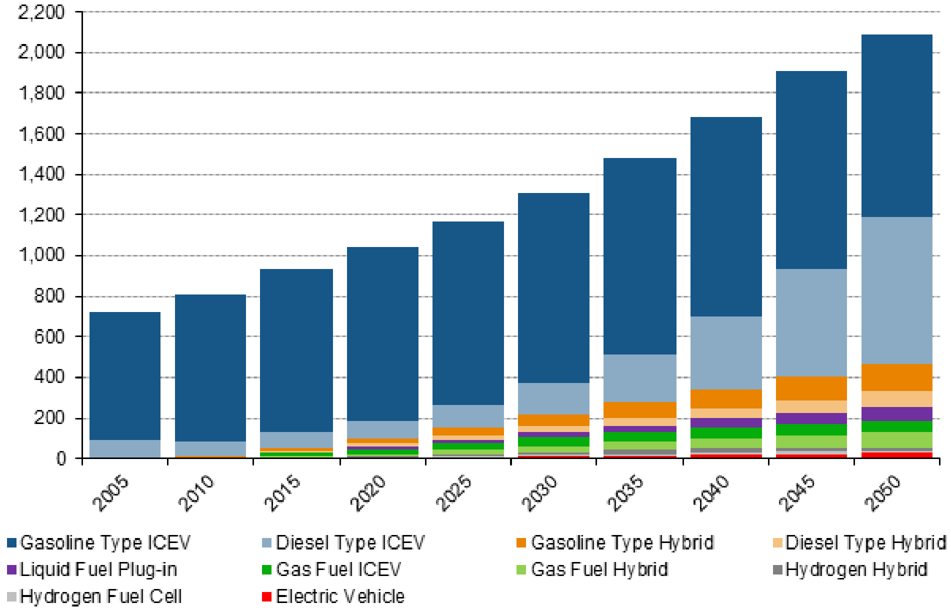


remaining 6% will be provided by electricity. Between 2010 and 2050, the bulk of the demand will be in the non-OECD countries rather than OECD countries and will be primarily conventional diesel (Figure 17b).

In the global transportation sector under Freeway there will be an increase of 82% in fuel demand and continuing dependence on gasoline (19%), diesel and fuel oil (50%), and jet fuel (20%), totalling 89% (Figure 18a). The remaining fuel share will be mostly biofuels (5%) and electricity (4%). As with the demand pattern for cars, the bulk of the demand will shift to the non-OECD countries (shares increasing from 40% to 67%) rather than OECD countries, and will still be dominated by the four major transport fuels, namely gasoline, diesel, fuel oil and jet fuel (Figure 18b).

Figure 19

Technology mix for cars (million)



Technology Mix

The modelling results of Freeway show that the global car fleet will still be dominated by a 78% share for the conventional liquid fuel ICEV (43% gasoline and 35% diesel). Gasoline and diesel hybrids are expected to constitute a market share of about 11% (7% gasoline and 4% diesel). The gas ICEV and gas hybrids are expected to be about 7% of the market (Figure 19). The remaining minority share is captured by electric, fuel cells, and plug-in vehicles.

Emissions

Although global fuel consumption for cars is expected to increase by about 51% between 2010 and 2050, CO_2 emissions from cars are expected to increase by only 36% (Figure 20). The relative drop in CO_2 emissions is primarily due to engine fuel-burning improvements and changes in fuel mix, namely consuming more biofuels and CNGs. As the figure shows, most of the increases in CO_2 emissions from cars are expected to come from emerging non-OECD markets, especially Asia

Figure 20

CO_2 emissions from cars ($GtCO_2/y$)

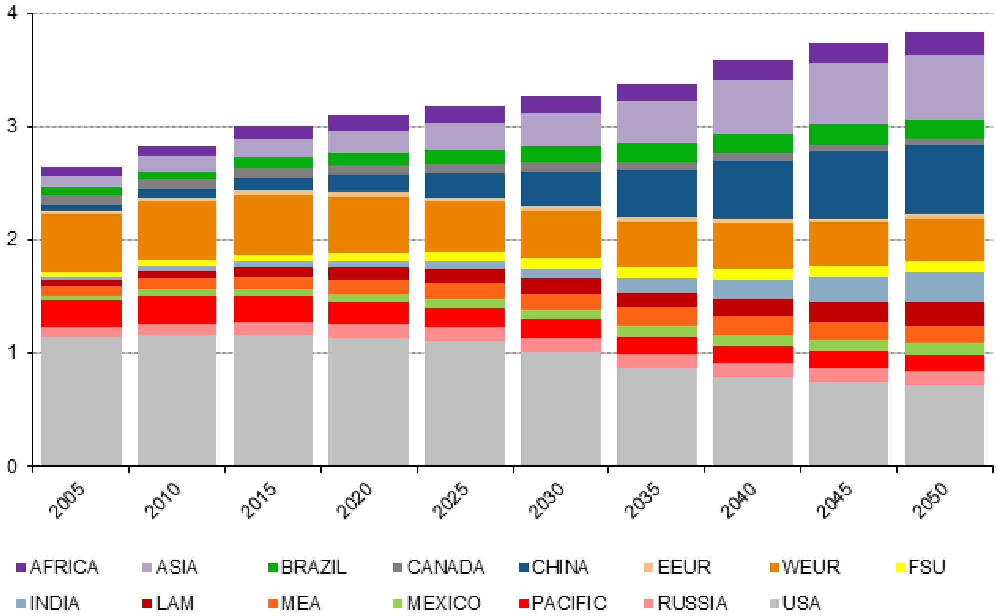
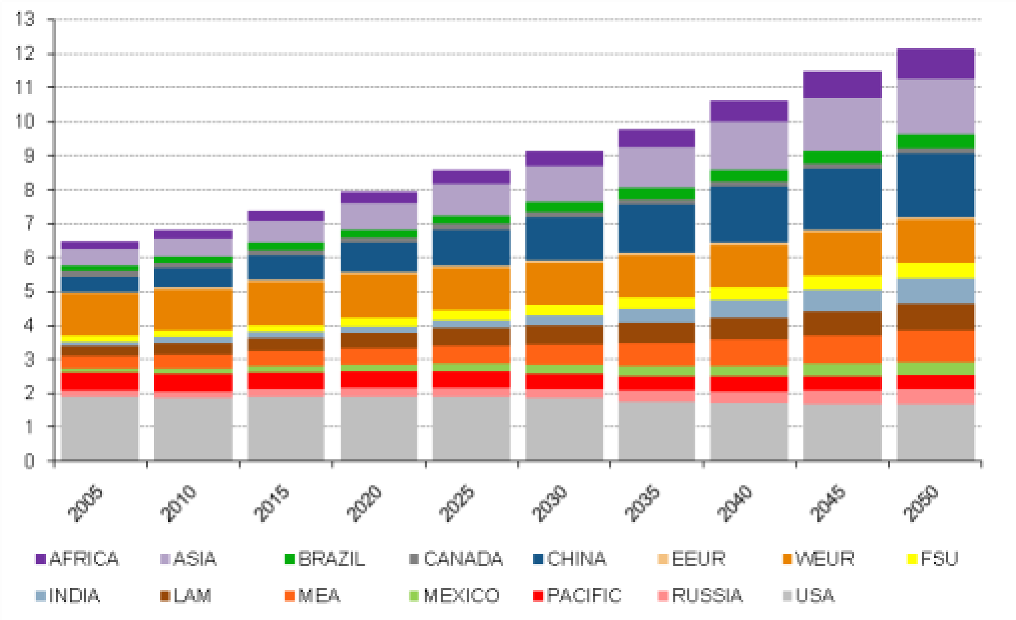


Figure 21

Total transport CO_2 emissions ($GtCO_2$/y)



(India increases seven-fold and China increases more than eight-fold). As the graph shows, CO_2 emissions from OECD countries in general are expected to drop (especially in the US, where they will drop by about 38%).

For the overall global transportation market, modelling results for Freeway suggest that the CO_2 emissions from transport will increase by 79% over the 2010 level (Figure 21). This is slightly smaller than the increase in demand of 81%. As with cars, slight improvements are expected, due to changes in fuel consumption efficiencies and mix. As with the CO_2 emissions from cars, the additional emissions are expected from the emerging non-OECD countries, especially Asia (India increases almost five-fold and China increases more than three-fold). The CO_2 emissions from OECD countries in general are expected to drop slightly (in the US it will drop by about 10%).

7.4 Results for Tollway

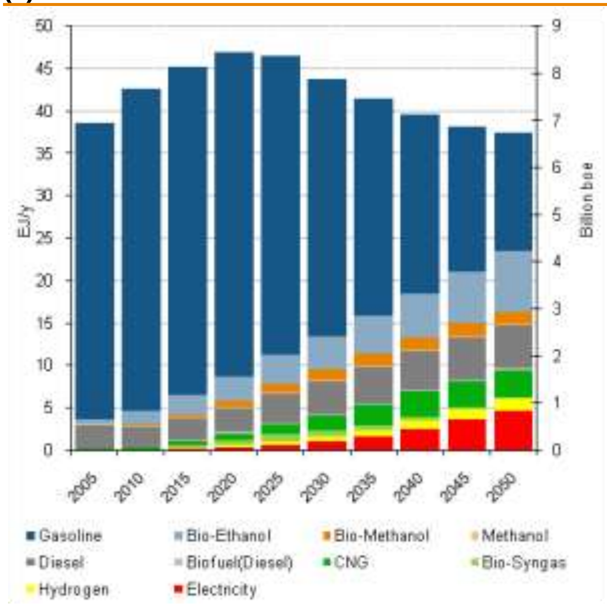
Fuel Demand

For Tollway, Figure 22a shows that the global fuel consumption for cars is expected to drop by about 13% between 2010 and 2050. Clearly, the world's

Figure 22

Fuels for LDV cars

(a) Demand between 2010 and 2050



(b) Demand of OECD vs. non-OECD (EJ)

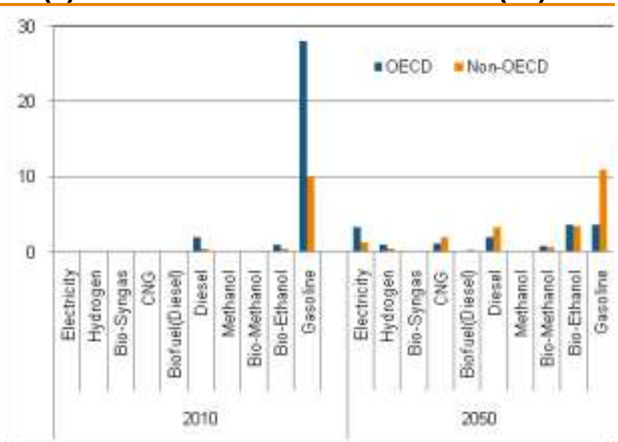


Figure 23

Fuel in other surface transport and aviation

(a) Demand between 2010 and 2050 (b) Demand of OECD vs. non-OECD (EJ)

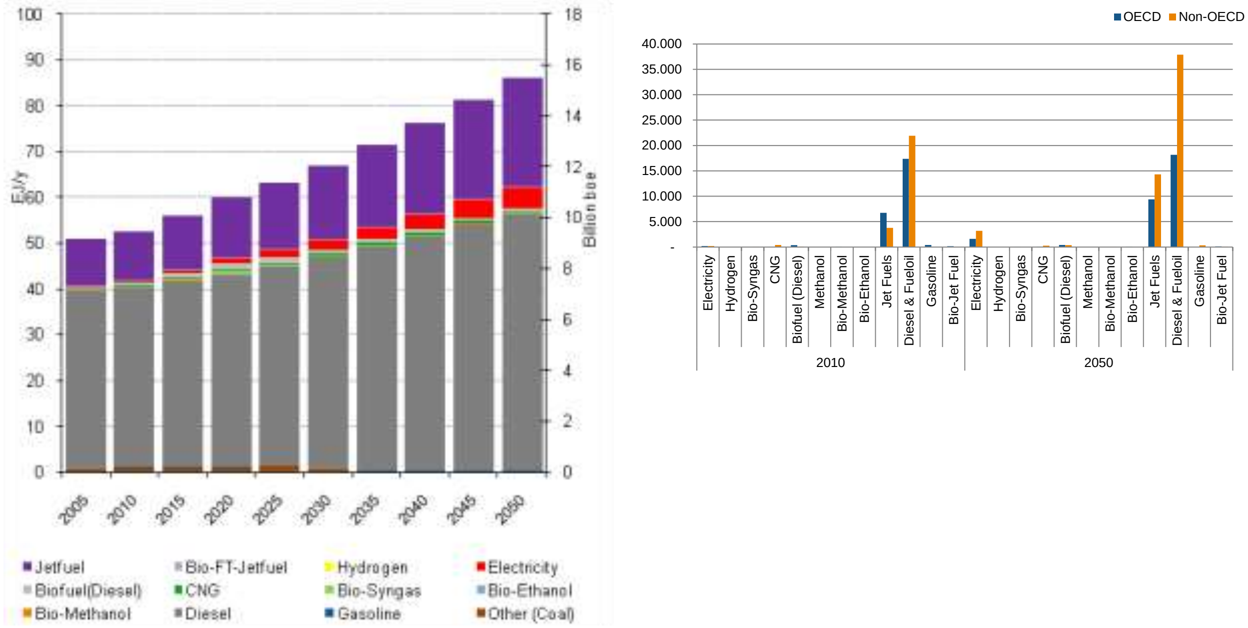
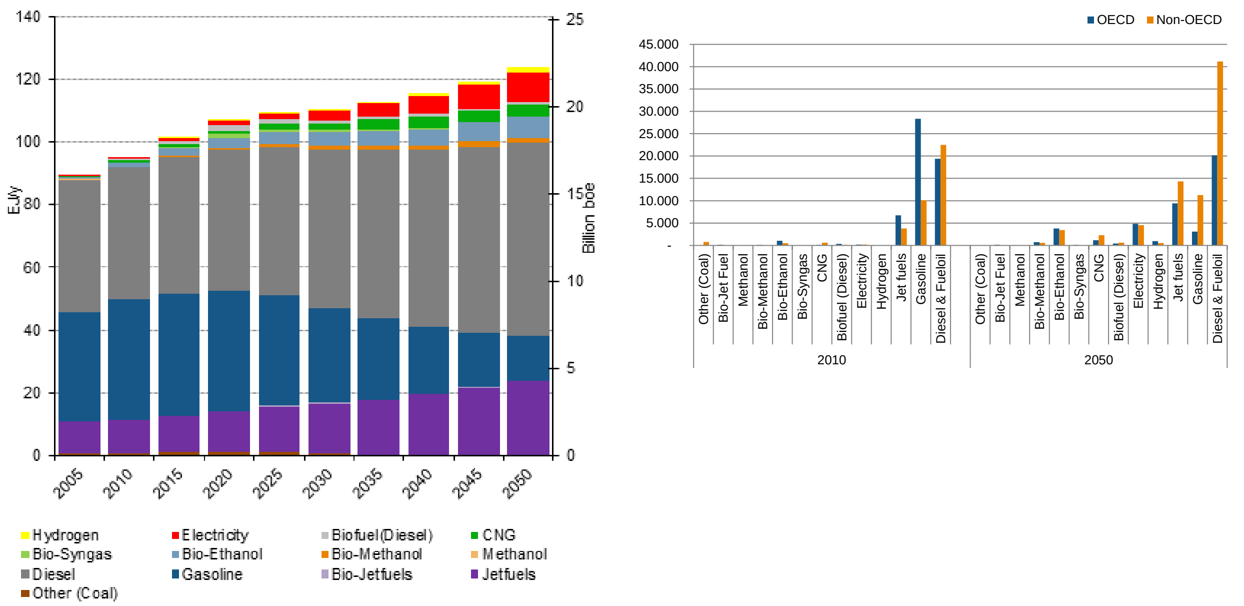


Figure 24

Fuels in all transport

(a) Demand between 2010 and 2050 (b) Demand of OECD vs. non-OECD (EJ)

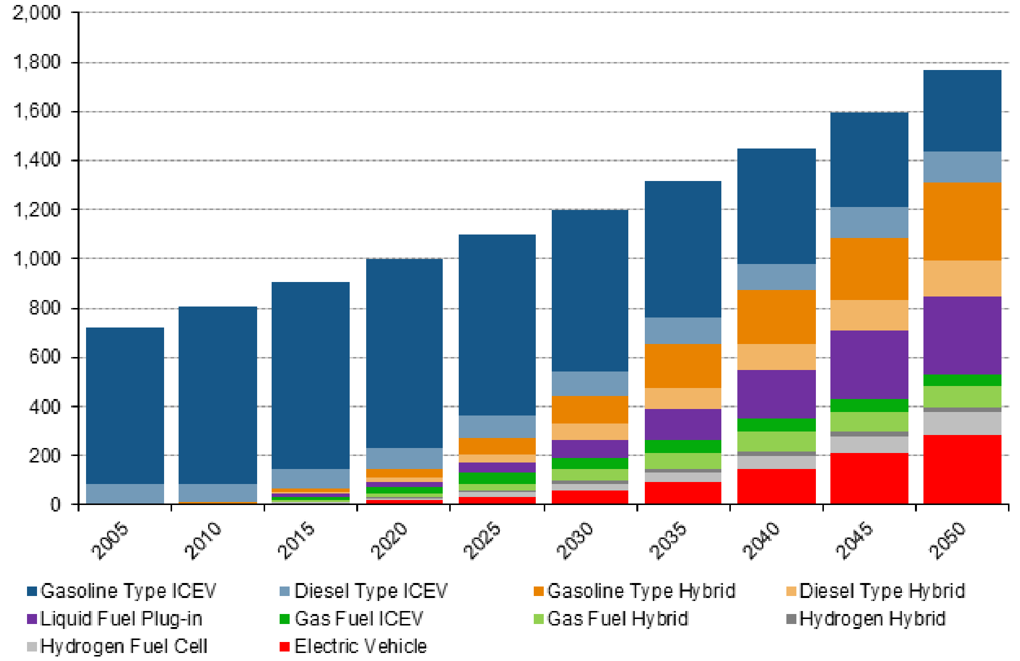


car fleet will still depend on fossil fuels as gasoline and diesel will still constitute about 52% of the fuel mix in 2050, comprising 38% for gasoline and 14% for diesel. Biofuels will increase to a higher level of around 24%, electricity will reach 12%, while CNG will be about 8%. The remaining demand will be satisfied by hydrogen, methanol, and syngas.

Comparing the demand pattern for car fuels between 2010 and 2050, we can see that the bulk of the demand will be in the non-OECD countries (increasing from 26% in 2010 to 62% in 2050), rather than OECD countries, and that the demand will still be dominated by gasoline and diesel (Figure 22b).

Figure 25

Technology mix for cars (million)



In contrast, the modelling results show that the global fuel demand for other surface transport and aviation in 2050 will increase by about 64% between 2010 and 2050 (Figure 23a). Again, the world will still depend on fossil fuels, of which diesel, fuel oil and jet fuel will comprise around 93%; and electricity will make up most of the remaining fuel demand (6%). These shares are almost the same as in Freeway, but the levels are about 20% lower. As with the demand pattern of cars, the bulk of demand will shift to the non-OECD countries rather than OECD countries, and will still be dominated by the two other major surface transport and aviation fuels, namely diesel and jet fuel (Figure 23b).

The results for the global transportation sector show that, overall, the sector will witness an increase of 30% in fuel demand and will still depend heavily on gasoline (12%), diesel and fuel oil (50%), and jet fuel (19%), totalling 81% (Figure 24a). The remaining fuel share will be mostly biofuels (7%), electricity (8%), and CNG (3%). To a certain extent, these shares are similar to those in Freeway, but the levels are generally lower. Comparing the demand of OECD and non-OECD countries, we can see from Figure 24b that the bulk of demand will shift to non-OECD countries (increasing from 40%–64%) and will still be dominated by the three major transport fuels, namely gasoline, diesel, and jet fuel, along with smaller shares of electricity and bioethanol.

Technology Mix

In Tollway, the global car fleet in 2050 will be very diverse, with shares of 26% for liquid fuel conventional ICEV (19% gasoline and 7% diesel); 26% for liquid hybrids (18% gasoline and 8% diesel); 18% plug-ins; 16% electric; 8% gas vehicles;, and 6% for others (Figure 25).

Emissions

Due to the 13% drop in global fuel consumption for cars between 2010 and 2050, CO_2 emissions from cars are also expected to drop by 46% (Figure 26). As with Freeway, the relative drop in CO_2 emissions is primarily due to engine fuel-burning improvements and the changes in fuel mix, namely consuming more biofuels and CNGs. As the figure shows, most of the reductions in CO_2 car emissions are expected from OECD markets (i.e., emissions in both US and Western Europe drop by about 80%). The significant reductions in OECD countries are met with significant increases in non-OECD countries, especially Asia (India increases about four-fold, while China increases about three-fold).

Figure 26

CO_2 emissions from cars ($GtCO_2$/y)

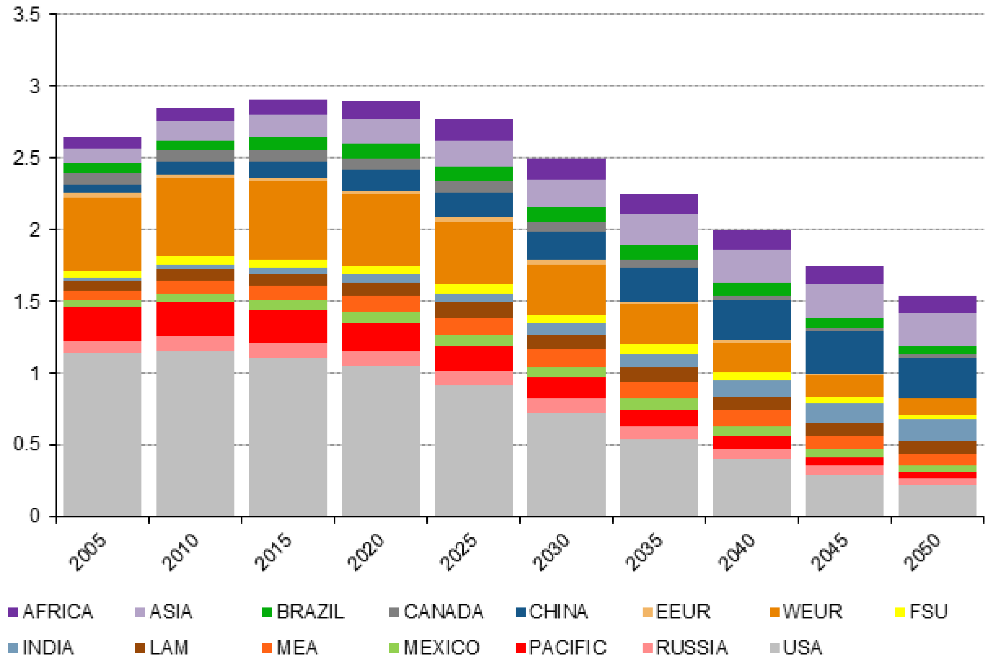
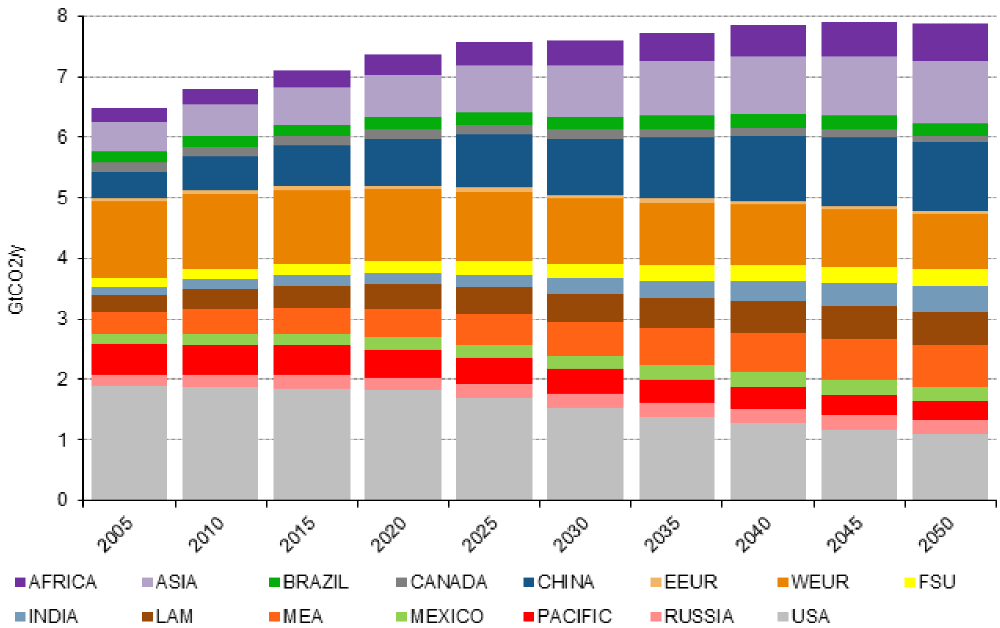


Figure 27

Total transport CO_2 emissions ($GtCO_2$/y)



Looking at the overall global transportation market, the modelling results show that the CO_2 emissions from transportation will increase by only 16% over 2010 levels (Figure 27). Clearly, this increase is slightly smaller than the demand increase of 30%. This is mainly due to changes in fuel consumption efficiencies and mix. As with CO_2 emissions from cars, the expected reductions are mostly from OECD countries (the US and Western Europe drop by 30–40%), while additional emissions are expected from the non-OECD countries, especially Asia (China doubling its emissions, and India tripling).

7.5 Comparison of Scenarios at a Global Level

Major Trade-Offs

The main difference between the two scenarios “Freeway” and “Tollway” is the degree and style of government intervention in regulating future transport sector.

The first and most important impact manifests itself in global fuel demand. The unregulated world of Freeway puts less emphasis on the development of public transport systems and shows significantly higher demand projections for all types of fuels at global level. Also, higher economic growth results in more vehicle ownership, increased traffic and freight movement, especially in non OECD markets.

In the Tollway scenario government intervention leads to earlier implementation of electric mobility and other non-fossil fuel options. While in the Freeway scenario the market will push for the lowest cost options, thereby favouring more efficient internal combustion engines and increasing hybridization as technology solutions. The take up of biofuels will be limited by global availability which are at similar levels in both scenarios but other alternative fuels (electricity, hydrogen, CNG and methanol) reach much higher levels in the Tollway scenario.

The resulting technology mix for mobility and transport will be more fossil fuel based in Freeway and a much more diversified mix in the Tollway scenario. As a consequence, total CO2 emission levels from the transport sector vary considerably between the two scenario outcomes, with Tollway showing emissions only 16% higher than 2010 whilst Freeway shows an increase of 79% compared to 2010.

A common trend between both scenarios is the emerging importance of air traffic and the heavy transport sector, causing a significant increase in demand for jet fuel and diesel fuel.

More detailed comparisons between the two scenarios are drawn in the following sections.

Fuel Demand

Between 2010 and 2050, the total fuel demand for cars (personal LDVs) increases by about 51% in Freeway, while in Tollway it peaks around the year 2020 and then gradually drops to 13% by the end of the scenario period (Figure 28a). Non-conventional fuels, including biofuels (bio-syngas, bio-methanol, bio-ethanol, and bio-diesel) and other fuels (electricity, hydrogen, CNG, and methanol) increase in both scenarios. Biofuels show an increase of about five-fold in both scenarios, while the other fuels show an increase of about twelve-fold in Freeway and about twenty-six-fold in Tollway.

Demand for gasoline and diesel combined increases by 28% in Freeway, and drops by 52% in Tollway (Figure 28b).

Energy demand for the other surface transport modes (trucks, buses, trains, and ships) and aviation reach higher levels under both scenarios (Figure 29a). The demand for biofuels in Freeway

Figure 28

Fuel demand for LDV cars (EJ)

(a) Total fuel demand for cars **(b) Diesel-Gasoline**

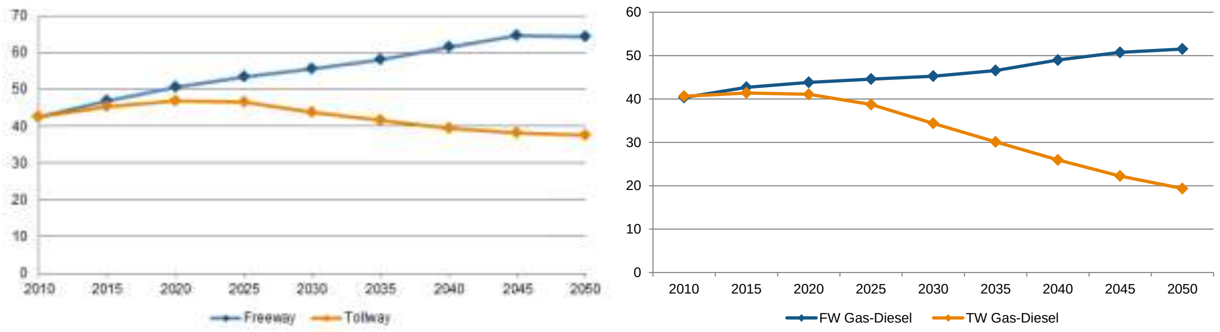


Figure 29

Fuel demand for other surface transport and aviation (EJ)

(a) Total fuel in other transport **(b) Gasoline/Diesel/Fuel oil/Jet fuel**

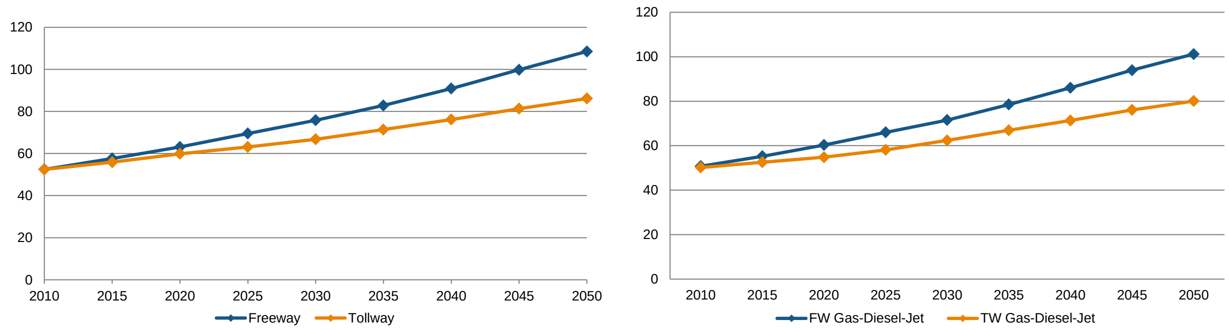
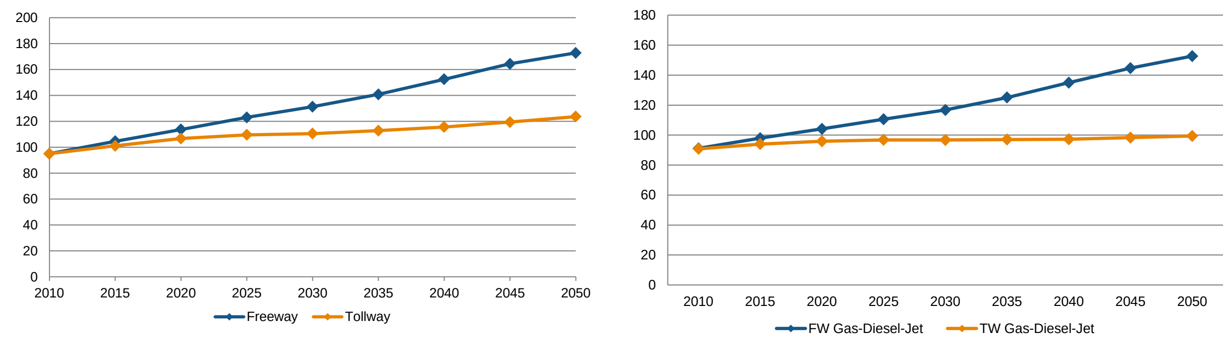


Figure 30

Fuels in all transport (EJ)

(a) Fuel demand in all transport **(b) Gasoline/Diesel/Fuel oil/Jet fuel**



is expected to remain at almost 2010 levels; while in Tollway, they increase 5.4 fold. The other fuels show an increase of more than 4.8-fold in Freeway, and 3.3-fold in Tollway.

The major source for these trends is the change in the demand for diesel, fuel oil and jet fuel (Figure 29b). In Freeway the demand for gasoline, diesel, and jet fuel is expected to double, while in Tollway, it is expected to increase by 60%.

Looking at the total fuel demand in all transport modes between 2010 and 2050, the modelling results reveal that the demand could increase by 30% in Tollway, and by about 82% in Freeway (Figure 30a). Similarly, the demand for biofuels increases by more than four-fold in both scenarios. The demand for other fuels reaches higher levels in both scenarios, increasing about 6-fold in Freeway and 7.6-fold in Tollway.

Figure 31

Fuel demand for OECD and non-OECD countries (EJ)

(a) Fuel demand in cars **(b) Fuel demand in all transport**

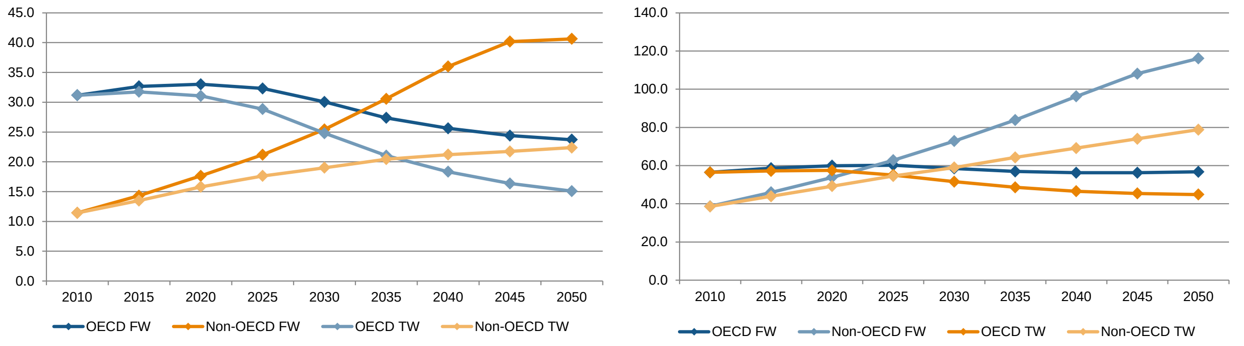
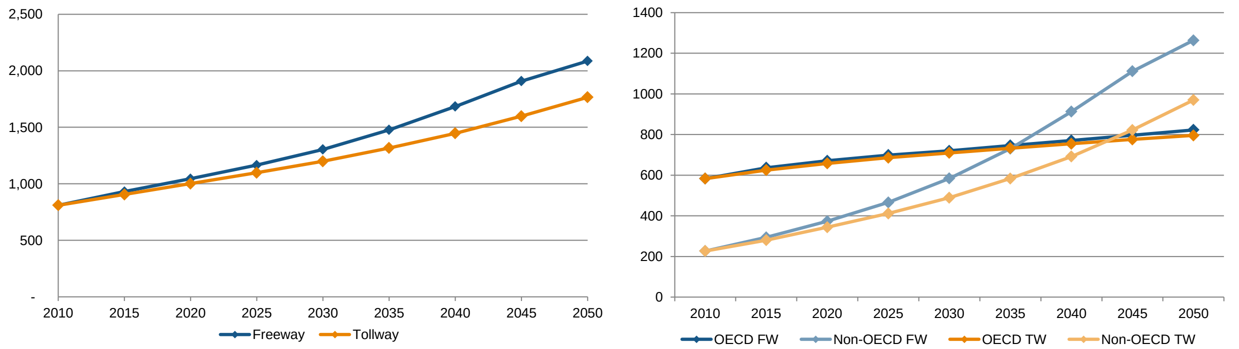


Figure 32

Technology mix for LDV cars (million)

(a) Number of cars between 2010 and 2050 **(b) Cars in OECD vs. non-OECD**



Clearly, the major source for the overall difference in fuel demand between the two scenarios is the level of demand for gasoline, diesel, and jet fuel (Figure 30b). In Freeway, the demand for gasoline, diesel, and jet fuel is expected to increase by 68% while in Tollway the demand is expected to increase by only about 10%.

The modelling results also show that, over the next four decades, growth in fuel demand for cars will be driven by the non-OECD countries (Figure 31a). As for the total demand for all transport fuels, the non-OECD countries are expected to show a three-fold increase in Freeway and about two-fold increase in Tollway (Figure 31b). As the figure shows, the non-OECD countries demand for transport fuels is expected to exceed that of the OECD countries by 2025 in Tollway, and earlier than 2025 in Freeway.

Technology Mix

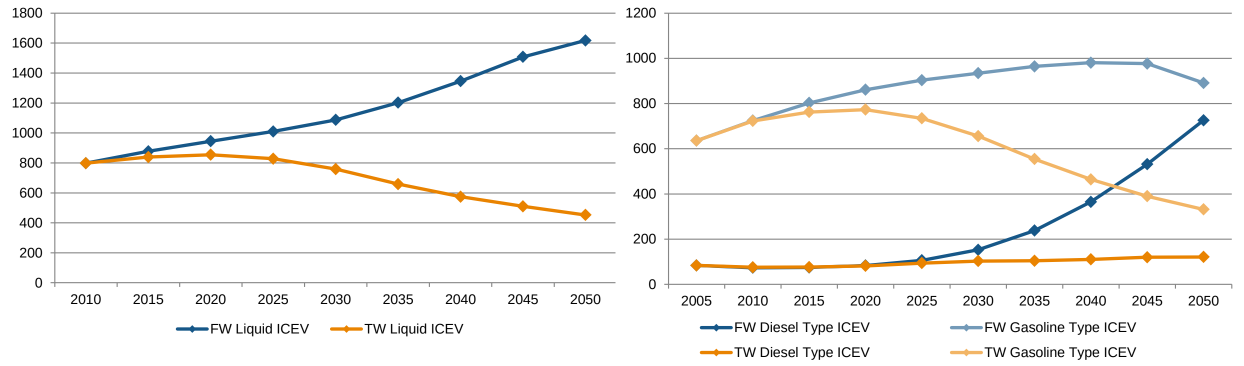
Due to the increase in GDP per capita and the increasing population, especially in non-OECD countries, the number of cars is expected to increase in both scenarios. Modelling results show that, over the next four decades, the number of cars could more than double. Freeway suggests an increase of about 2.6 times the 2010 levels, while Tollway suggests a lower increase of 2.2 times the 2010 level (Figure 32a). The difference between the two scenarios originates mostly from the non-OECD countries. The number of cars in the non-OECD countries is expected to increase 4.3-fold in Tollway and 5.57-fold in Freeway. For the OECD countries, the number of cars is expected to increase by about 36% in Tollway and 41% in Freeway (Figure 32b).

Looking at the technology used in each scenario, we see that under Freeway, the number of conventional ICEVs burning either gasoline or

Figure 33

Technology mix for LDV gasoline-diesel ICEVs (million)

(a) Gasoline-diesel ICEVs between 2010 and 2050 (b) Gasoline vs. Diesel ICEVs



diesel almost doubles. However, Tollway shows a general drop in the number of ICEVs by about 43% below the 2010 level (Figure 33a). Furthermore, disaggregating these trends into gasoline and diesel engines, we can see from Figure 33b that, by the end of the scenario period, the number of gasoline ICEVs in Freeway increases by 23% over the 2010 levels, while the number of diesel ICEVs increases about ten-fold. The overall drop of ICEVs in Tollway is due to gasoline ICEVS dropping by about 54%, while the number of diesel ICEVs increases by about 61%.

Looking at the other drive-train technologies, we can see from Figure 34 that they all increase under both scenarios, but rather more under Tollway (on the right and-side graph). As the figure shows, the highest increase in both scenarios is for the liquid hybrids (mostly gasoline). The gas ICEVs (conventional and hybrid) also show a significant growth in both scenarios, reaching about 133 million cars, mostly in the US and Western Europe.

The larger share will be in the US (more than one-third of the global natural gas fleet) as a result of the significant breakthroughs in shale gas technologies. The plug-in, electric, and hydrogen vehicles flourish under the Tollway scenario reaching 320, 288, and 190 million respectively. The expectations for the hydrogen LDVs may seem high, but these figures are from the extreme end of the possibilities for these scenarios.

Figure 34

Other technology LDV cars (million)

(a) Freeway (b) Tollway

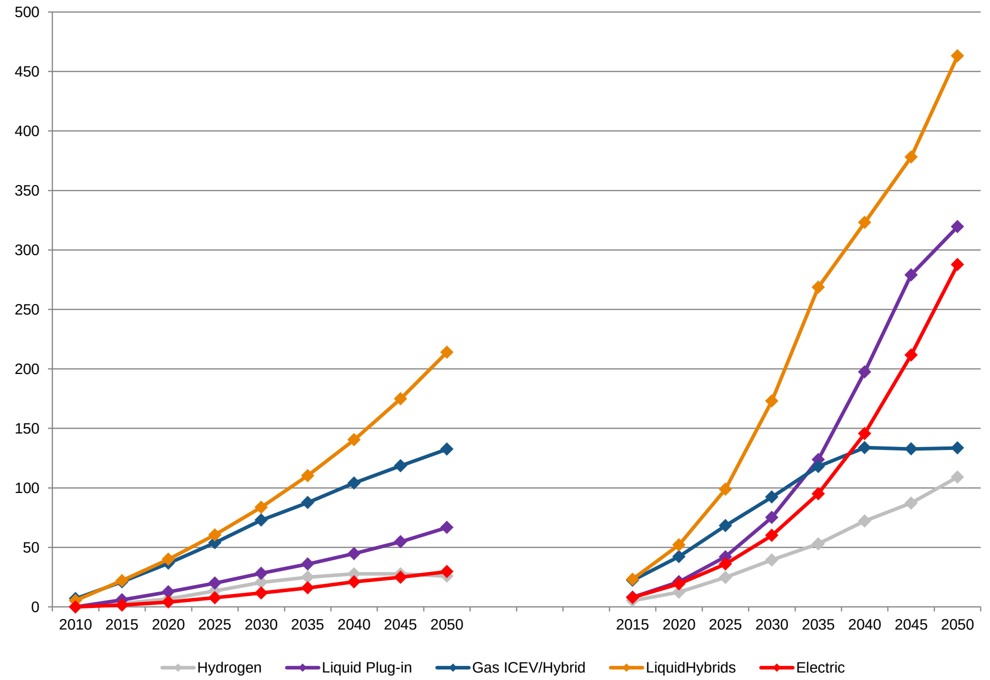


Figure 35

CO_2 emissions from LDV cars ($GtCO_2$)

(a) Global CO_2-emissions from LDV cars **(b) CO_2-emissions from LDV car OECD vs. non-OECD**

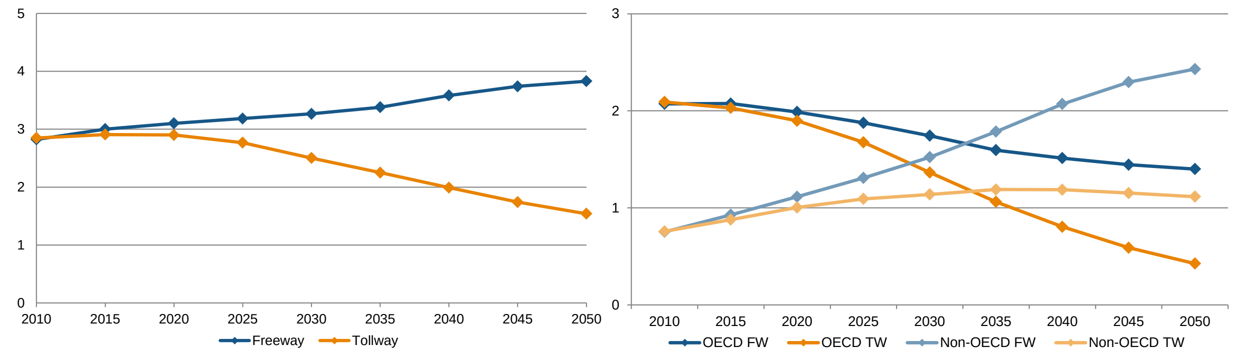
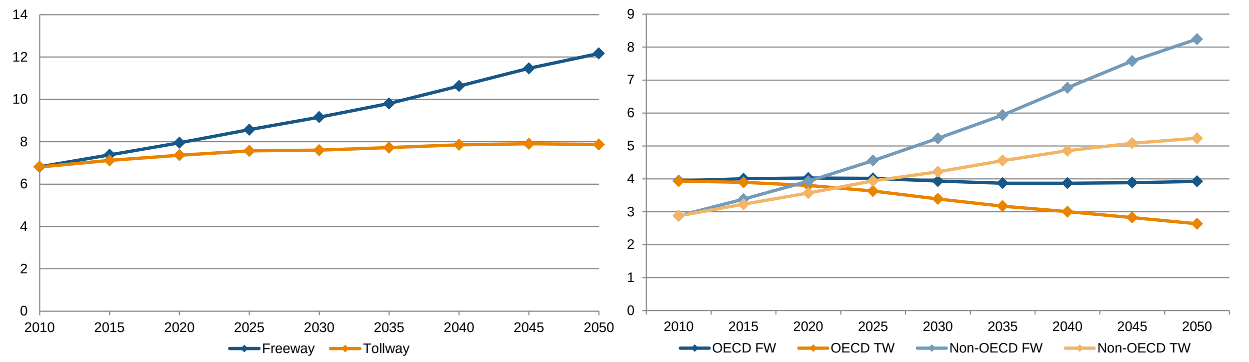


Figure 36

CO_2 emissions ($GtCO_2$)

(a) Global CO_2 emissions from transport **(b) Global CO_2 emissions transport OECD vs. non-OECD**



Emissions

The spans noted in transport fuel demand cause corresponding spans in CO_2 emissions. Freeway shows that the CO_2 emissions from cars are expected to increase by about 35% between 2010 and 2050 (Figure 35a). This is despite the fact that demand is expected to increase by about 51%. The disproportionate levels are due to the changing fuel consumption mix and the fact that engines are becoming more efficient. In contrast, Tollway shows that CO_2 emissions from cars in 2050 are likely to drop by about 46% below 2010 levels. Again, this is due to three factors, including a drop in demand in 2050 by 13% below 2010 levels, a changing fuel consumption mix, and increases in engine efficiencies. In addition, the modelling results presented in Figure 35b show CO_2 emissions from non-OECD countries increasing in both scenarios (323% in Freeway and 47% in Tollway). Emissions in OECD countries are expected to fall in both scenarios (32% in Freeway and 80% in Tollway).

Looking at the CO_2 emissions from the overall transport sector in 2050, Freeway shows the level to be about 79% higher than the 2010 level. In Tollway, CO_2 emissions levels are expected to be only 16% higher than the noted 2010 level (Figure 36a). This is despite an expected rise in the fuel demand for transport of between 30% (in Tollway) and 82% (in Freeway). The disproportional results come from a gain in fuel-burning efficiency and a change in fuel consumption mix in all transport modes. Looking at Figure 36b, we can see that the total transport CO_2 emissions are expected to increase in non-OECD countries in both scenarios (287% in Freeway and 82% in Tollway), while emissions from the OECD are expected to fall by 33% in Tollway and remain the same in Freeway.

8. Conclusions

The two scenarios described and modelled in this report describe two divergent global transportation futures looking out to 2050. We envision the actual world to be somewhere in the middle. In this section, we summarize the findings of the scenarios, and then briefly discuss their implications for the future of transportation.

Between 2010 and 2050, total fuel demand in all transport modes will increase by 30%-82% over 2010 levels. This growth is mainly driven by trucks, buses, trains, ships, and airplanes: demand for these forms of transport is expected to increase by 64%-200%. Fuel demand for the LDVs, which constitutes about 52% of the transport market, is expected to increase by 51% in Freeway and drop by 13% in Tollway.

In addition, the transportation sector will still depend heavily on gasoline, diesel, and jet fuel, since they all constitute the bulk of transport market fuels (80%–88%). The demand for these three fuels will increase by 10%-68% over the scenario period. Most of the growth will be in diesel and jet fuel: diesel will grow by 46%-200%, while jet fuel will grow by 200% to 300%. In contrast, the demand for gasoline is expected to drop by 16%-63%. Biofuels will also help to satisfy the demand for transport fuel: their use will increase almost four-fold. The demand for other fuels (electricity, hydrogen, CNG, and methanol) will increase six- to seven-fold.

In the LDV market, fuel demand for cars will still depend heavily on gasoline and diesel which will satisfy 52%–80% of the demand. However, growth in demand will be limited to diesel, increasing by 200%-900%, while the gasoline demand drops by 16%-63%.In addition, the remaining fuel demand from cars will be satisfied by biofuels, which will grow about five-fold and other fuels, which will grow twelve- to twenty-six-fold.

The rest of the transport market and the aviation market will still depend heavily on diesel and jet fuels, which will satisfy 93% of the fuel demand. The demand for diesel will increase by 42%-65%, while the demand for jet fuel will increase by 225%-380%. The remaining demand will be satisfied by biofuels, which are expected to increase by up to 540%, and other fuels, which will increase by 330%-480%.

Over the scenario period, all the additional transport fuel demands will come from the non-OECD countries, where demand will grow by 200%-300%. In contrast, the transport fuel demand for the OECD countries will drop by up to 20%. Similarly, fuel demand for cars in the non-OECD countries is expected to increase by 96%-355% while it will drop by 24%-52% in the OECD. The total fuel demand increases in the non-OECD countries and drops in the non-OECD countries: by the end of the scenario period, demand in the non-OECD countries will be 60%–70% of the demand while that in the OECD countries will be 30%–40% of the demand. The demand of the non-OECD countries surpasses that of the OECD countries by the year 2025, if not earlier.

The total number of cars in the world will also increase 2.2 to 2.6 times, mainly in the non-OECD countries, where the number of cars will increase by 430%-557% while the OECD countries will see an increase of 36%-41%. By the end of the scenario period, non-OECD countries will have about 55%–61% of the global fleet (global fleet estimated at 1,766 to 2,086 million cars). The global car fleet will still depend on conventional gasoline and diesel ICEVs, with a market share between 26% and 78%. Growth in the global car fleet will mainly be in diesel ICEVs, which will grow by 61%-1,000%, while the number of gasoline ICEVs could drop by 54% in Tollway or increase by 23% in Freeway. Other drive-train technologies will capture the remaining market share with liquid hybrid, plug-ins, and electric vehicles leading in Tollway, while hybrids, plug-ins and gas vehicles lead in Freeway.

With these higher levels of transport demands, the total CO_2 emissions from the transportation sector are expected to increase by 16%-79%. This increase in CO_2 emissions will not be proportional to the increase in total demand (30%–82%), due to changes in fuel consumption mixes and increases in efficiencies. As most of the demand (60%–70%) will be in the non-OECD countries, the bulk of the CO_2 emissions in 2050 will also be in the non-OECD countries (around 67%), with car emissions constituting 20%–32% of the total.

With this picture of the transport sector in 2050, and in light of the previously discussed major drivers, we believe that the global transport sector can and will overcome the many challenges of meeting the global transport demand at the lowest social costs. The biggest of these challenges will be to provide sustainable transport for more than six billion urbanized people with the minimum possible congestion, pollution, and noise generated by additional traffic and freight.

Indeed, understanding the dynamics and magnitude of these likely future developments can offer consumers, entrepreneurs, governments, and private businesses the opportunity to adjust their future plans and expectations. We have no doubt that the birth of dialogue between consumers and producers, the findings of additional conventional and unconventional energy resources, the expansions in the use of renewables, the improvements in technologies, and the selection of optimal policies tailored to suit each region's needs will all ensure a sustainable transport future and will raise the quality of life for current and future generations.

Key Takeaways for Policymakers

At a strategic level some important messages emerge for policy makers.

- The absolute levels of increase in transport volumes and fuel demand will largely depend on the type of government policies put in place over the next few decades. Government policies will impact the number and technology mix of cars and trucks on the road, and emissions resulting from additional transport activity.
- We expect to experience a marked shift in transport fuel demand from the developed countries to the developing ones, mostly China and India.

- Global transport will remain heavily dependent on fossil fuels with a strong rise in demand for diesel, fuel oil and jet fuel compared to gasoline. This will have potentially significant implications for refiners and the downstream sector as a whole, especially in Europe, where there is a large emphasis on diesel fuels. The global demand increase for diesel is largely driven by demand from the heavy transport, agriculture, and mining sectors. In these segments replacement of conventional fuels with new types of fuel technologies is unlikely to occur prior to 2050. The same holds true for fuel oil in shipping and jet fuel for aviation.

- The maximum level of biofuels in the liquids markets is expected to be around four times above current market levels. Water and land use restrictions will prevent much further growth. Biofuels tend to be regional phenomena, mostly concentrated in the Americas, with sugar cane biofuels being dominant in Brazil and corn ethanol being the dominant biofuel in United States. The use of biofuels in Europe is largely a result of government mandates. As for the alternative fuels including natural gas, electricity and hydrogen, the maximum level is expected to be six to seven times above the current levels depending on the degree of government intervention.

- It is evident that without strong government regulation, putting public interest and common good before individual concerns, transport markets will tend to develop along the lines of business as usual and little progress will be made in developing infrastructure and technologies to reduce the negative impacts of transport.

Now is the time for strong leadership at both government and enterprise levels if the transport sector is to make a positive contribution towards the well-being of future generations.

Glossary

BEV	battery electric vehicle
BRT	bus rapid transit
CAFE	corporate average fuel economy
CNG	compressed natural gas
CNGV	compressed natural-gas vehicle
CTC	coal to liquid
EIA	US Energy Information Administration
EV	electric vehicle
FAO	Food and Agriculture Organization
FCV	fuel cell vehicle
FDI	foreign direct investment
FFV	flexible fuel vehicle
FSU	former Soviet Union
GDP	gross domestic product
GHG	greenhouse gas
GRT	ground rapid transit
GTL	gas to liquid
HEV	hybrid electric vehicle
HFCV	hydrogen fuel-cell vehicle
HFCV	hybridized fuel-cell vehicle
HSR	high-speed rail
IANGV	International Association for Natural Gas Vehicles
ICEV	internal combustion engine vehicle
IFC	International Finance Corporation
IMF	International Monetary Fund
LDV	light duty vehicle
NEDC	New European Driving Cycle
NGO	non-governmental organisation
NOC	national Oil Company, fully or in the majority owned by a national government
O&M	operations and maintenance
OCED	Organization for Economic Cooperation and Development
PRT	personal rapid transit
R&D	research and development
toe	tonne oil equivalent
UNIDO	United Nations Industrial Development Organization
UNPD	United Nations Population Division
USGS	United States Geological Survey
WB	World Bank
WEF	World Economic Forum
WTO	World Trade Organisation

Figures and Tables

List of Figures

List of Tables

Apendices

Appendix A: Detailed Scenario Description and Regional Inputs
http://www.worldenergy.org/documents/WECTransportScenariosAppendix.pdf

Appendix B: Model's Input Assumptions (Exogenous Parameters)
http://www.worldenergy.org/documents/WECTransportScenariosAppendix.pdf

Appendix C: Model's Outputs (Endogenous Variables)
http://www.worldenergy.org/documents/WECTransportScenariosAppendix.pdf

Member committees of the World Energy Council

Albania
Algeria
Argentina
Austria
Belgium
Bolivia
Botswana
Brazil
Bulgaria
Cameroon
Canada
Chad
China
Colombia
Congo (Democratic Republic)
Côte d'Ivoire
Croatia
Cyprus
Czech Republic
Denmark
Egypt (Arab Republic)
Estonia
Ethiopia
Finland
France
Gabon
Germany
Ghana
Greece
Hong Kong, China
Hungary
Iceland
India
Indonesia
Iran (Islamic Republic)
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea (Republic)
Kuwait
Latvia
Lebanon
Libya/GSPLAJ
Lithuania
Luxembourg
Macedonia (Republic)
Mexico
Monaco
Mongolia
Morocco
Namibia
Nepal
Netherlands
New Zealand
Niger
Nigeria
Pakistan
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russian Federation
Saudi Arabia
Senegal
Serbia
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Swaziland
Sweden
Switzerland
Syria (Arab Republic)
Taiwan, China
Tajikistan
Tanzania
Thailand
Trinidad & Tobago
Tunisia
Turkey
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay

World Energy Council
Regency House 1-4 Warwick Street
London W1B 5LT United Kingdom
T (+44) 20 7734 5996
F (+44) 20 7734 5926
E info@worldenergy.org
www.worldenergy.org

For sustainable energy.

ISBN: 978-0-946121-14-4