



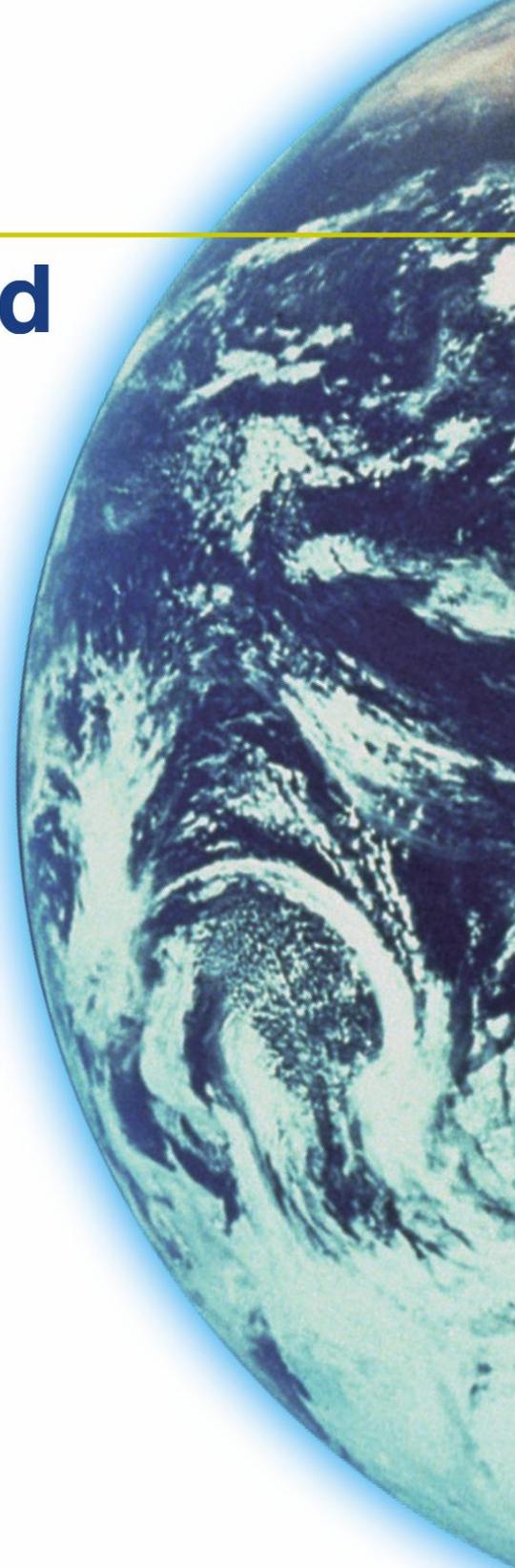
**Asia-Pacific  
Economic Cooperation**

# APEC

## Energy Demand and Supply Outlook 5th Edition

### Economy Reviews

February 2013



**APERC**

Asia Pacific Energy Research Centre

# APEC ENERGY DEMAND AND SUPPLY OUTLOOK

## 5TH EDITION

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ECONOMY REVIEWS

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**ASIA PACIFIC ENERGY RESEARCH CENTRE**

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## TABLE OF CONTENTS

Foreword.....	ii
Acknowledgements.....	iii
List of Abbreviations.....	viii
Tables of Approximate Conversion Factors .....	xi
Australia.....	1
Brunei Darussalam.....	11
Canada .....	21
Chile .....	33
China .....	43
Hong Kong, China .....	55
Indonesia .....	65
Japan.....	79
Korea .....	89
Malaysia .....	97
Mexico .....	109
New Zealand.....	123
Papua New Guinea.....	133
Peru .....	141
Philippines.....	155
The Russian Federation .....	167
Singapore.....	175
Chinese Taipei.....	183
Thailand.....	193
United States.....	203
Viet Nam.....	215

## FOREWORD

We are pleased to present the *APEC Energy Demand and Supply Outlook – 5th Edition*. This Outlook is designed to provide a basic point of reference for anyone wishing to become more informed about the energy choices facing the APEC region.

Concerns about energy security, the impacts of energy on the economy, and environmental sustainability are becoming increasingly important drivers of policy in every APEC economy. The business-as-usual projections presented here illustrate the risks of the development path the APEC region is currently on. A new feature of this Outlook is the alternative scenarios, which examine options for increasing natural gas use and reducing energy demand in transportation.

Readers who desire a quick overview of our most important findings should read Chapter 1, “Summary of Key Trends”. Readers who desire a quick overview of our business-as-usual projections should read Chapter 2, “APEC Energy Demand and Supply Overview”. Because of the summaries provided in these two chapters, an Executive Summary would be redundant and is not included. Detailed tables of the model results are available on the APERC website <http://aperc.iecej.or.jp/>.

This report is the work of Asia Pacific Energy Research Centre (the ‘we’ used throughout this report). It is an independent study, and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. But we hope that it will serve as a useful basis for discussion and analysis of energy issues both within and among APEC member economies.

I would like to express a special thanks to the many people outside APERC who have assisted us in preparing this report, as well as to the entire team here at APERC. We at APERC are, of course, responsible for any errors that remain.

I would especially like to acknowledge the contributions of my predecessor as APERC President, Kenji Kobayashi. Under Mr. Kobayashi’s leadership, the *Outlook – 5th Edition* project was already well-organized and underway when I joined APERC in July 2012.

Takato Ojimi  
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We wish to express our appreciation to the APERC Annual Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

We also would like to thank members of the APEC Energy Working Group (EWG), the APEC Expert Group on Energy Data and Analysis (EGEDA), and the APERC Advisory Board, along with numerous government officials, for their helpful information and comments.

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## LIST OF ABBREVIATIONS

### APEC ECONOMIES

AUS	Australia
BD	Brunei Darussalam
CDA	Canada
CHL	Chile
CT	Chinese Taipei
HKC	Hong Kong, China
INA	Indonesia
JPN	Japan
MAS	Malaysia
MEX	Mexico
NZ	New Zealand
PE	Peru
PNG	Papua New Guinea
PRC	People’s Republic of China
ROK	Republic of Korea
RP	the Republic of the Philippines
RUS	the Russian Federation
SIN	Singapore
THA	Thailand
US or USA	United States of America
VN	Viet Nam

### ORGANIZATIONS AND INSTITUTIONS

ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of South-East Asian Nations
CIA	Central Intelligence Agency (USA)
EDMC	Energy Data and Modelling Centre (of IEEJ)
EIA	Energy Information Administration (USA)
EWG	Energy Working Group (of APEC)
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of the Petroleum Exporting Countries
WTO	World Trade Organisation
UN	United Nations

**TECHNICAL TERMS**

BAU	business-as-usual
bcf	billion cubic feet
bcm	billion cubic metres
bpd	barrels per day
BRT	bus rapid transit
BTU	British thermal unit
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and sequestration
CDM	Clean Development Mechanism
CNG	compressed natural gas
CO <sub>2</sub>	carbon dioxide
CSP	concentrated solar power
DSM	demand-side management
EOR	enhanced oil recovery
EV	electric vehicles
FCV	fuel cell vehicles
FED	final energy demand
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
g/kWh	grams per kilowatt-hour (used to measure the emissions caused by the generation of one unit of electricity)
GNP	gross national product
GTL	gas-to-liquids
GW	gigawatt
GWh	gigawatt-hour
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell
IOC	international oil companies
IPP	independent power producers
kgoe	kilogram of oil equivalent
km	kilometre
ktoe	thousand tonnes of oil equivalent
kW	kilowatt
kWh	kilowatt-hour
LEAP	Long-range Energy Alternatives Planning System
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
mbd	million barrels per day
mcm	million cubic metres
MEPS	minimum energy performance standards

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Mmbls	million barrels
mmscf	million standard cubic feet
MBTU	million British thermal units
MOU	memorandum of understanding
MPa	megapascals
MRT	mass rapid transit
MSW	municipal solid waste
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWp	megawatts peak
NAFTA	North American Free Trade Agreement
NGV	natural gas vehicle
NRE	new renewable energy
NYMEX	New York Mercantile Exchange
NO <sub>x</sub>	nitrogen oxides
PHV	plug-in hybrid vehicles
PJ	petajoules
PPP	purchasing power parity
PSC	production sharing contract
PV	(solar) photo-voltaic
R&D	research and development
R/P	reserves-to-production ratio
SO <sub>x</sub>	sulphur oxides
SUVs	Sports Utility Vehicles
T&D	transmission and distribution
tcf	trillion cubic feet
tcm	trillion cubic metre
toe	tonnes of oil equivalent
TPES	total primary energy supply
TWh	terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical (coal power generation technology)
USD	US Dollar

## TABLES OF APPROXIMATE CONVERSION FACTORS

### Crude Oil\*

From	To				
	tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	<b>Multiply by</b>				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US Gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

\* Based on worldwide average gravity

### Products

	To convert			
	barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	<b>Multiply by</b>			
Liquefied natural gas (LPG)	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

### Natural Gas (NG) and Liquefied Natural Gas (LNG)

	To					
	billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	<b>Multiply by</b>					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

### Units

1 metric tonne	= 2204.62 lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187 kJ = 3.968 Btu
1 kilojoule (kJ)	= 0.239 kcal = 0.948 Btu
1 British thermal	= 0.252 kcal unit (Btu) = 1.055 kJ
1 kilowatt-hour (kWh)	= 860 kcal = 3 600 kJ = 3 412 Btu

### Calorific Equivalents

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural Gas (NG) and Liquefied Natural Gas (LNG) table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil  
1 barrel of biodiesel = 0.88 barrel of oil

Reproduced from the *BP Statistical Review of World Energy June 2012* with the kind permission of BP p.l.c.



# AUSTRALIA

- *Australia's new Clean Energy Future package, which includes a carbon trading mechanism, is likely to see an increase in energy efficiency and decrease in overall CO<sub>2</sub> emissions in the long term.*
- *Due to its considerable coal seam gas reserves, Australia is likely to become a strategic producer of unconventional gas within the outlook period.*
- *Annual CO<sub>2</sub> emissions from fuel combustion are projected to decrease by 1.4% over the outlook period; this can largely be attributed to Australia's commitment to increasing the use of renewable energy, particularly in electricity generation as well as the switch from coal to gas.*

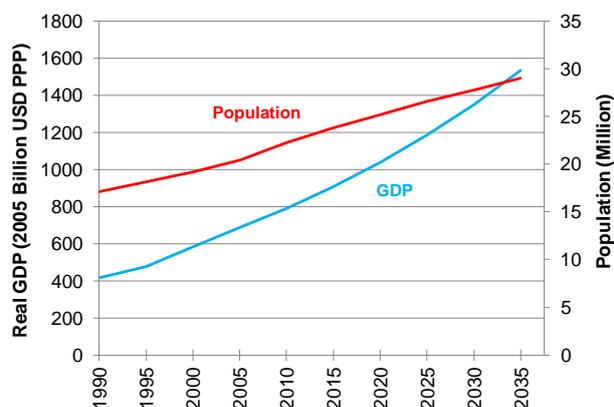
## ECONOMY

Australia is the world's largest island economy, and the sixth largest economy (in land area) in the world. It lies in the southern hemisphere, between the Indian and Pacific Oceans. Its total land area of nearly 7.7 million square kilometres is made up of the mainland, the major island of Tasmania, and other small islands. Australia has no land boundaries with other economies; its ocean neighbours include Indonesia, East Timor, Papua New Guinea, the Solomon Islands, Vanuatu, New Caledonia, and New Zealand.

The Australian mainland is largely desert or semi-arid land. A temperate climate and moderately fertile soils are found in the southeast and southwest corners, while the far north is characterized by a tropical climate (warm all year) and a mix of rainforests, grasslands and desert.

As of June 2011, Australia's population was 22.6 million people, mostly concentrated along the eastern and south eastern coast, and some on the west coast. Across the total landmass the population density (three people per square kilometre) is one of the lowest in the world. Nearly 92% of the population live in urban areas; the average household is a family of no more than four.

**Figure AUS1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Australia is rich in mineral resources and is a major world producer of bauxite, coal, gold, copper, nickel, zinc and iron ore—some concentrated in a particular region, others dispersed across its six states and two territories. The minerals sector is a substantial contributor to the Australian economy, with minerals production increasing over the past decade. Historically, mineral discoveries in Australia have been characterized by high-grade deposits and surface mineralization (Hogan, 2003); most of the surface mineralization has been developed and future mining activities are expected to be more energy intensive. The majority of Australia's resource production is exported, accounting for significant export earnings.

Australia has developed a world-class minerals processing industry to complement its mining industry; the three major areas are alumina refining, aluminium smelting, and iron-and steel-making.

Australia is one of the world's largest alumina producers with production estimated at 19.3 million tonnes in 2011–12 (BREE, 2012e).

Australia is also a significant exporter of iron ore, with the majority of exports going to China. Future iron ore production and exports are supported by a number of significant iron ore projects expected to be completed in the foreseeable future (BREE, 2012c). Other energy-intensive industries of note in the Australian economy include other non-ferrous metals processing (aluminium), non-metallic mineral production, and chemical and associated production.

Agriculture in Australia is a highly commercialized, technology-based, export-orientated industry, with exports such as dairy products, grain and live cattle going mostly to Southeast Asia and the Middle East. Agriculture and the associated industries of food, beverages and tobacco, wood, and pulp and paper are important contributors to the economy.

Australia's harsh and wide-flung geography makes road transport a crucial element in the

economy; Australia has three to four times more road per capita than Europe, and seven to nine times more than Asia. The rail network is slighter than the road system, although train networks are established within cities and between states.

Air travel, domestic and international, has grown rapidly since the early 1990s, particularly with the emergence of budget airlines. Generally, while cars are the usual mode of travel between rural centres, and cars or train the mode between rural centres and state capitals, air transport is the most economic form of travel between state capitals.

## ENERGY RESOURCES AND INFRASTRUCTURE

Australia has abundant coal reserves and is one of the world's leading coal producers and exporters. At the end of 2011, Australia's recoverable coal reserves stood around 86 billion tonnes (Geoscience Australia, 2011b), with estimated production in 2011–12 of 219.2 million tonnes (BREE, 2012e). Australia's economic reserves are sufficient to sustain current black coal production rates for nearly 100 years. Brown coal economic reserves are estimated to be able to sustain current production for over 500 years (BREE, 2012a). Coal is the dominant primary energy source in Australia; in 2008–09, it accounted for 39% of primary energy consumption in the economy (BREE, 2011, p. 30). Coal use is heavy in the power generation sector, where it currently accounts for more than 70% of the generation mix (BREE, 2011, p. 30). Over 80% of coal produced in Australia is exported.

Environmental issues, in particular climate change, are expected to have a strong influence on the future of Australian coal exports and domestic consumption. The industry is focused on the development and deployment of 'clean and green' coal conversion and storage technologies. In addition, the Australian Government's efforts in promoting coal-to-liquids technology and carbon sequestration could play an important role in shaping future domestic coal consumption, especially in meeting the rising domestic demand for transport fuels.

Natural gas has become the fastest growing fossil fuel in terms of production and consumption in Australia. According to the CIA's World Factbook, at the end of 2010 Australia had an estimated 3.115 trillion cubic metres of proven natural gas reserves, which places it within the top 15 of economies with proven natural gas reserves (USCIA, 2011). The majority of Australia's conventional gas resources are located off the northwest coast of Western Australia,

which makes this the largest gas-producing region in Australia. However, the rise of non-conventional gas resources in the eastern region, such as coal seam gas reserves, means gas production is forecast to increase significantly in the east in the outlook period.

On average between 2010–11 and 2011–12 Australia's production of natural gas (including natural gas from coal seam methane projects) is estimated to be about 52.7 billion cubic metres (BREE, 2012e). About 35% of this production is exported as liquefied natural gas (LNG), mostly within the Asia-Pacific region (ABARES, 2011). Environmental concerns about energy use have provided a boost to natural gas use in Australia. Federal and state policy initiatives have encouraged the use of cleaner energy resources, including natural gas, which has a lower CO<sub>2</sub> emissions factor than coal or oil. Combined with its security of supply, natural gas will be the preferred choice for many Australian energy consumers. The power generation, manufacturing and mining sectors are all expected to significantly increase the share of natural gas in their energy mix in the medium and long term.

Australia has significant reserves of coal seam gas (CSG). As at the end of 2010, Australia had economic demonstrated resources of 35 055 petajoules (PJ), but only produced 175 PJ (0.5% of the economic demonstrated resources) in that year (Geoscience Australia, 2011a). Due to environmental risks associated with the extraction of CSG, such projects need to undergo a comprehensive and sometimes lengthy approvals process overseen by the respective state government. There are three LNG-CSG projects under construction currently, with environmental impact studies being conducted on two other CSG projects (BREE, 2012b). In 2011, CSG was produced only in Queensland and New South Wales, where it accounted for the majority of each state's total gas production. Production of CSG is expected to strengthen in the future with LNG plant plans already in place based on production and export from Queensland (BREE, 2012d).

As of the end of 2010, Australia's total oil economic demonstrated resources were estimated at 22 161 PJ—made up of 12 413 PJ of condensate, 5685 PJ of crude oil and 4063 PJ of liquefied petroleum gas (LPG) (BREE, 2012a). Australia's proven oil reserves are not as impressive as that of its coal, accounting for about 2% of the world's proven reserves. Most of Australia's oil reserves are located in the Carnarvon Basin, Gippsland Basin, Bonaparte Basin, Cooper–Eromanga Basin, and Bass Basin; these areas cover the north, west, southeast and southern regions of Australia. Australia is a net oil importer, in 2011 Australia's crude oil and

condensate production was 425 614 barrels per day, with imports in the year around 554 270 barrels per day (BREE, 2012e). Australia's oil production has been declining since 2003—this is due to natural depletion (especially in the Cooper–Eromanga Basin and Gippsland Basin), lack of new exploration fields coming online, and higher exploration costs for unexplored resources located offshore (in deep water). There is some export of crude oil, particularly heavy crude from wells in the northwest.

Petroleum products are the main energy source for the transport and mining sectors in Australia. In 2008–09, they accounted for 35% of primary energy consumption in the economy, second only to coal. Within the transport sector there are a range of alternative low-carbon fuels that have the potential to complement or replace conventional oil, but they need further research, development and demonstration before they can be adopted (BREE, 2011). While hybrid and electric vehicles are available in Australia the price competitiveness of conventional vehicles generally beats out these forms of automobile transportation.

Australia has enormous potential renewable energy resources, especially wind, solar, geothermal and hydro. While in 2009–10 only 2% of total energy produced in Australia was from renewable sources (predominantly bio-energy), Australia's Clean Energy Future plan and its Renewable Energy Target (both discussed under 'Energy Policies') emphasize Australia's commitment to renewable energy and should therefore see its further development (BREE, 2012a). The National Electricity Market (NEM) was established in 1998 to allow the inter-jurisdictional flow of electricity between the Australian Capital Territory, New South Wales, Queensland, South Australia and Victoria (Tasmania joined the NEM in 2005). Western Australia and the Northern Territory are not connected to the NEM because of their distance from the rest of the market. The NEM comprises a wholesale sector and a competitive retail sector. All electricity dispatched must be traded through the central pool, where output from generators is aggregated and scheduled to meet demand.

## ENERGY POLICIES

Australia enjoys a high level of energy security characterized by low-priced, reliable energy supplies and a significant natural endowment of energy resources, including coal, natural gas, crude oil and considerable potential for renewable energy. Underpinning Australia's natural resources are extensive infrastructure and well-functioning domestic and international energy markets.

The Australian Government released a draft Energy White Paper (EWP) on 13 December 2011. The consultation process included public forums in each state capital across Australia and 285 written submissions were received. The final Energy White Paper is due to be released at the end of 2012.

The EWP promotes well-functioning markets supported by efficient and effective regulatory frameworks to deliver competitively priced energy. The core objective is to build a secure, resilient and efficient energy system that provides accessible, reliable and competitively priced energy for all Australians; to enhance Australia's domestic and export growth potential; and to deliver clean and sustainable energy. The four key priority areas outlined in the draft EWP are strengthening the resilience of Australia's energy policy framework; delivering better energy market outcomes for consumers; developing Australia's critical energy resources—particularly gas resources; and accelerating clean energy outcomes.

An update to the 2009 National Energy Security Assessment (NESA) was released in December 2011. The 2011 NESA found that Australia's overall energy security situation is expected to remain adequate and reliable, but it will increasingly be shaped by the strength of new investment going forward and the price of energy, which are both materially influenced by global trends (DRET, 2011c). The 2011 NESA was a key input into the development of the draft Energy White Paper.

On 10 July 2011, the Australian Government announced the Clean Energy Future plan, which makes the move from the previous Clean Energy Initiative and other government programs to a comprehensive plan to reduce Australia's greenhouse gas emissions. The Clean Energy Future includes:

- the introduction of a carbon price
- the promotion of innovation and investment in renewable energy
- encouragement for energy efficiency
- the creation of opportunities in the land sector to cut pollution.

The carbon pricing mechanism establishes a fixed carbon price of AUD 23 (USD 24) per tonne (rising at 2.5% per year in real terms) for the period 1 July 2012 to 30 June 2015. The carbon price will apply to around 500 of Australia's largest greenhouse gas emitters. Around 60% of Australia's emissions will be directly covered by the carbon pricing mechanism, and around two-thirds will be covered by a combination of the mechanism and equivalent carbon pricing arrangements. From 1 July 2015, the

carbon price will become flexible under a ‘cap and trade’ emissions trading scheme, with the price largely determined by the market. Emissions units will be able to be traded from 1 July 2015, and a lower and upper limit of emissions unit prices will apply for the first three years beyond 1 July 2015 (DCCEE, 2011a).

The Australian Government does not undertake or finance energy resource exploration or development. In the petroleum sector, the government relies on an annual acreage release to create opportunities for investment. The release, distributed worldwide, is a comprehensive package that includes details of the acreage, bidding requirements and permit conditions. All foreign investment proposals in Australia are subject to assessment and subsequent government approval through the Foreign Investment Review Board.

The approvals process for unconventional gas exploration is overseen by each responsible state government, under the Environment Protection and Biodiversity Conservation Act 1999. In this process each state assesses applications from each company looking to explore in their area, and then declines or grants access; this can be quite a lengthy process. Similarly, the assessment of safety requirements and environmental regulation for the coal industry is carried out by the state in which each project is based.

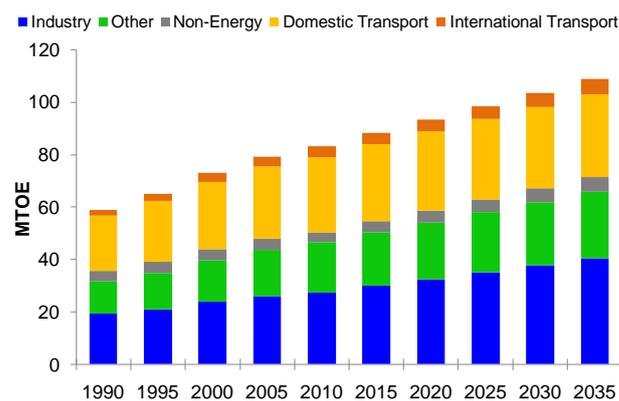
The Australian Government has a number of policies and programs in place to capitalize on the potential economic growth and emissions reduction resulting from improved energy efficiency within the industrial, transport, and residential and commercial sectors. There is also a suite of policies and initiatives introduced over the last few years to increase the role of renewable energy. This includes the Renewable Energy Target, which requires 45 000 GWh of electricity generation to be sourced from renewable energy by 2020. The Renewable Energy Target has been separated into a Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES), to provide greater certainty for households, for large-scale renewable energy projects and for installers of small-scale renewable energy systems. Combined, the new LRET and SRES are expected to deliver more renewable energy than the overall Renewable Energy Target (DCCEE, 2011b). Other measures promote low-carbon energy research, development, demonstration and deployment including the Global Carbon Capture and Storage Institute.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Final energy demand under business-as-usual (BAU) assumptions is expected to grow at an annual average rate of 1% over the outlook period. Most of this growth can be attributed to increases in energy consumption across all sectors, especially in the industrial and ‘other’ (residential, commercial and agricultural) sectors.

Figure AUS2: BAU Final Energy Demand

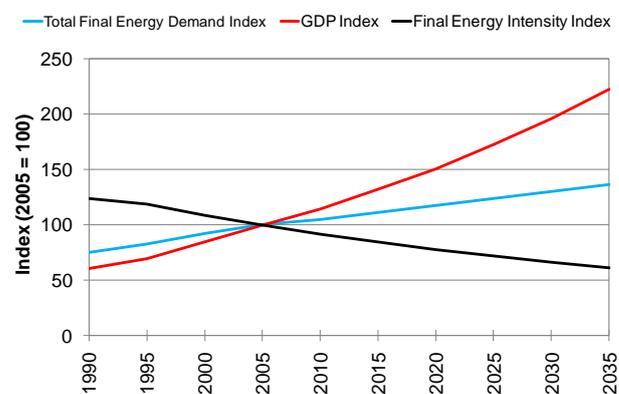


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Despite this increase in final energy demand, final energy intensity (as shown in Figure AUS3) is expected to decline by 39% between 2005 and 2035.

Figure AUS3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industrial sector is projected to grow at an average annual rate of 1.6% between 2010 and 2035. This reflects the steady but relatively slow growth of Australia’s industrial sector in general, along with Australia’s focus on the services sector. However, given that Australia is experiencing a mining boom, energy consumption in this sector is expected to increase (on average 2.2% a

year over the outlook period) in tandem with the rapidly growing industry.

Combustible fuels are expected to account for the majority of industrial energy demand, with consumption increasing by more than 45% over the outlook period.

### Transport

Vehicle ownership in Australia has very nearly reached saturation level. The transportation energy demand of Australia is projected to grow by 10% over the outlook period.

Given the lack of incentives for consumers to shift to vehicles using alternative fuels, virtually all transport-based energy consumption will be of oil products. Conventional gasoline vehicles will account for a greater proportion of vehicles, comprising more than half of the light vehicle fleet by 2035. Conventional diesel vehicles will make up the second highest share of the light vehicle fleet (17%), while vehicles using alternative fuels will account for only a small share.

### Other

Australia has many policies promoting energy efficiency within the residential and commercial sectors. Through building codes and standards Australia promotes energy efficiency within commercial buildings. In the residential space the government has retrofit programs promoting initiatives such as installation of energy-efficient lighting.

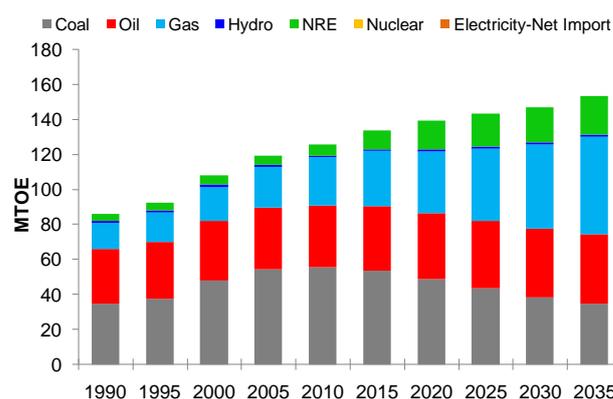
However, such efforts will be offset by a growing population and an increasingly consumer-driven society, which is likely to result in the use of more electrical gadgets and home appliances. Energy demand in the ‘other’ sector, which includes residential, commercial, and agricultural demand, is expected to grow at an average annual rate of 1.1% over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for 55% of ‘other’ energy consumption in 2035.

## PRIMARY ENERGY SUPPLY

Australia’s primary energy supply between 2010 and 2035 is projected to grow at an average annual rate of 0.8%.

Given the potential for significant production of natural gas from unconventional sources, Australia is expected to increase its production of gas in the outlook period. Primary supply of gas is projected to nearly double between 2010 and 2035.

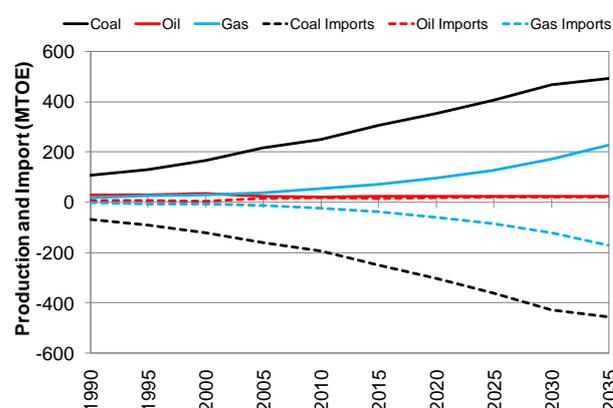
Figure AUS4: BAU Primary Energy Supply



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics2011 © OECD/IEA 2011

Coal will dominate energy supply in most of the first part of the outlook period (2010–2027), with an average share of 37% over those years. Although much of the gas produced will be exported as LNG, predominantly to economies in the Asian region, gas is expected to overtake coal in domestic energy supply in the latter half of the outlook period, accounting for 36% of primary energy supply in 2035.

Figure AUS5: BAU Energy Production and Net Imports

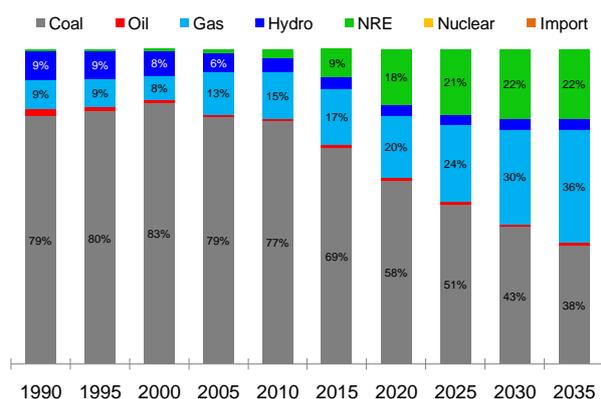


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics2011 © OECD/IEA 2011

## ELECTRICITY

Australia’s coal reserves mean this fuel will dominate the electricity generation mix in the outlook period. However, the Australian Government’s commitment to energy efficiency and the promotion of renewable energy makes it highly likely that the economy will at least very nearly achieve its goal of 20% electricity sourced from renewable energy by 2020. This will bring about a reduction in the role of coal in the electricity generation mix over the outlook period, as with increased contribution from natural gas and NRE (predominantly wind).

Figure AUS6: BAU Electricity Generation Mix

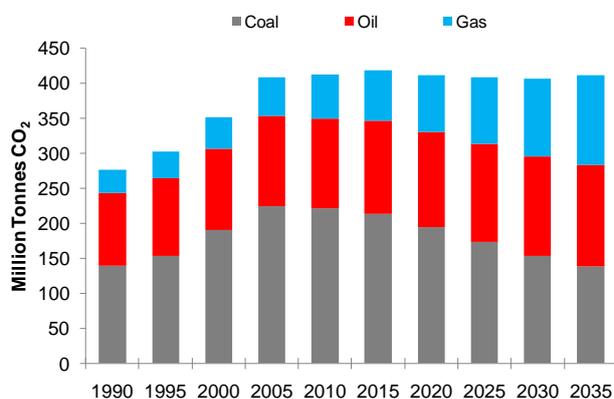


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

CO<sub>2</sub> EMISSIONS

Over the outlook period Australia’s total CO<sub>2</sub> emissions from fuel combustion are projected to decrease by 0.3 million tonnes from 2010 to 2035, to 412.3 million tonnes. This decrease in emissions can be attributable to Australia’s policies promoting renewable energy in the household and commercial sectors. Most notable, however, is Australia’s push to increase use of renewable energy sources in electricity generation; in particular wind power capacity is expected to increase by 30–35% over the outlook period. This structural change will be a key factor in emissions reduction.

Figure AUS7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

Table AUS1 indicates that emission increases due to GDP growth will be offset by a reduction in both the CO<sub>2</sub> intensity of energy (contributed by fuel switching from coal to gas and NRE) and energy intensity of GDP from effective energy efficiency measures, which will lead to a modest reduction in total CO<sub>2</sub> emissions over the outlook period.

Table AUS1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.4%	-1.7%	-0.8%	-0.7%	-0.5%
Change in Energy Intensity of GDP	-1.2%	-0.9%	-1.9%	-1.9%	-2.2%
Change in GDP	3.4%	2.7%	2.7%	2.7%	2.7%
Total Change	2.6%	0.2%	0.0%	0.0%	0.0%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, the Australian energy outlook is steady. However, as demand for cleaner sources of fuel such as natural gas increases globally over the outlook period, Australia may wish to expedite regulation and exploration processes in order to maximize its sizeable natural gas resources.

ALTERNATIVE SCENARIOS

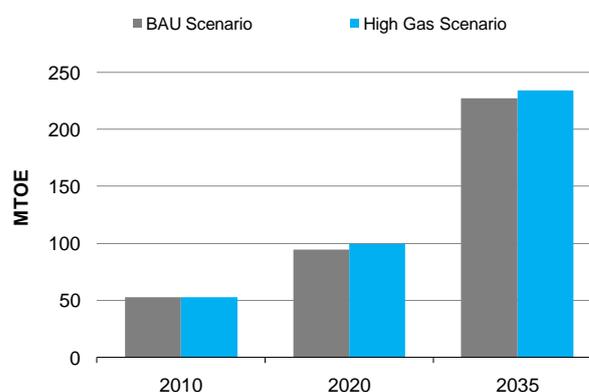
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Australia assumed the production increase shown in Figure AUS8, which equals 3% by 2035. This was based on expanding Australia’s current unconventional and conventional gas development given its strong customer base in the Asia–Pacific region.

Figure AUS8: High Gas Scenario – Gas Production



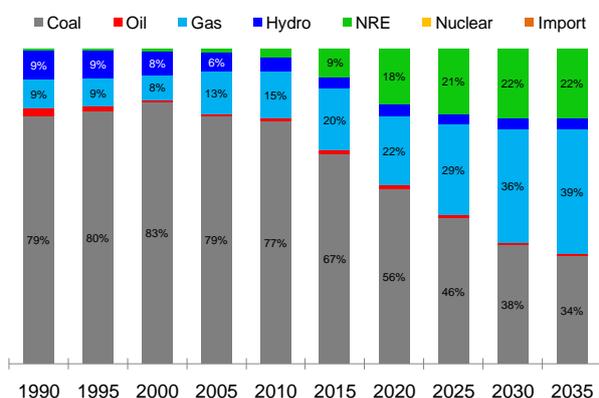
Source: APERC Analysis (2012)

Even under BAU assumptions, Australia’s gas production is expected to increase significantly over the outlook period. The slight additional increase in gas production under the alternative scenario can be attributed to the assumption that the sometimes cumbersome and lengthy approvals processes will be improved and expedited to allow more gas projects to become operational.

Additional gas consumption in each economy in the High Gas Scenario depends not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. Given the perceived environmental benefits of gas over coal, a portion of the gas produced will be consumed locally. However, given Australia’s modest population in terms of its gas reserves, the majority of the additional gas is expected to be exported.

Figure AUS9 shows the High Gas Scenario electricity generation mix for Australia. This graph may be compared with the BAU scenario graph in Figure AUS6. It can be seen the gas share has increased by 3% by 2035, while the coal share has declined by 4%. It is interesting to note that under the alternative scenario gas has a greater share than coal in the electricity generation mix by 2035. However, even under the BAU case, gas would only be 2% shy of the share of coal in the generation mix by 2035, a substantial change from 2010.

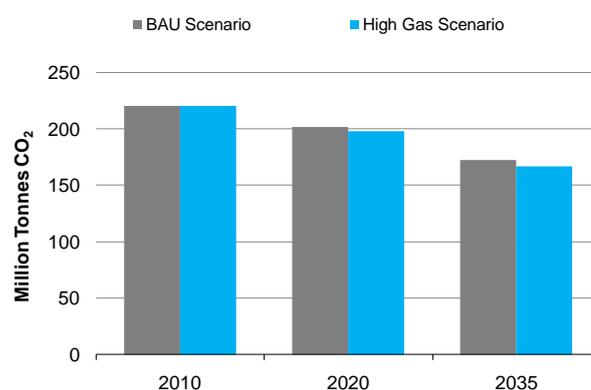
**Figure AUS9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The additional domestically-consumed gas in the High Gas Scenario was assumed to replace coal in electricity generation. Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by nearly 5% in 2035. Figure AUS10 shows this CO<sub>2</sub> emission reduction which is significant given Australia’s GDP growth.

**Figure AUS10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



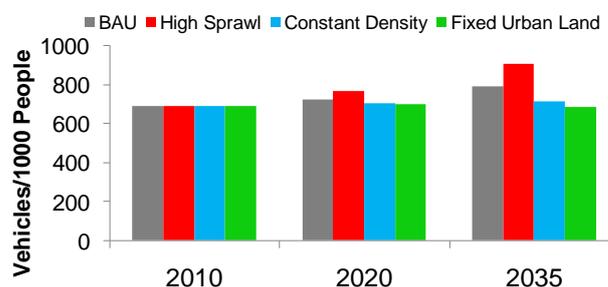
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure AUS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. If Australia’s cities were to stay at a constant population density it is expected that there will be a decrease in vehicle ownership of 10% in 2035 compared to the BAU case. The High Sprawl case would result in an expected 15% increase in vehicle ownership by 2035 compared to BAU.

**Figure AUS11: Urban Development Scenarios – Vehicle Ownership**

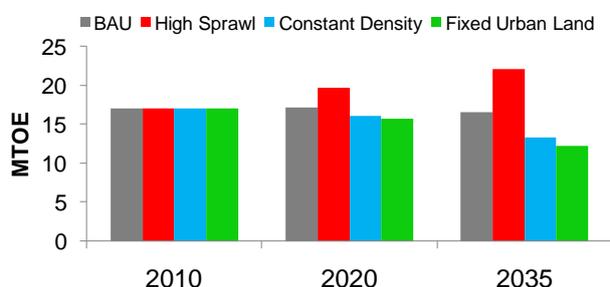


Source: APERC Analysis (2012)

Figure AUS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The High Sprawl scenario is likely to see 33% more light vehicle oil consumption in 2035 compared to BAU. Under the Constant Density and Fixed Urban Land scenarios, there were reductions in light vehicle oil consumption

of 19% and 26% respectively in 2035 compared to BAU. This demonstrates the benefits of better urban planning.

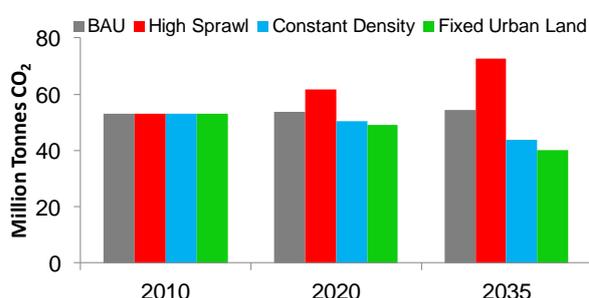
**Figure AUS12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure AUS13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure AUS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



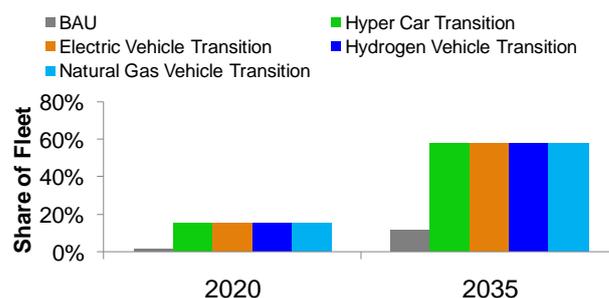
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure AUS14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 58% compared to about 11% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 42%, compared to about 89% in the BAU scenario.

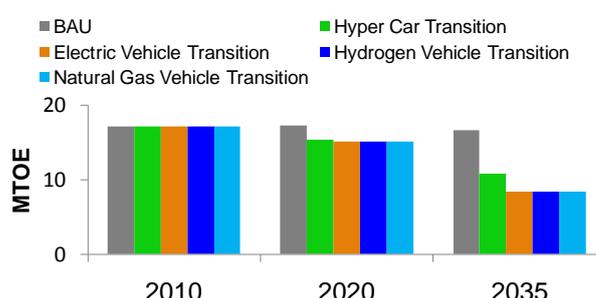
**Figure AUS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure AUS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly efficient vehicles still use oil.

**Figure AUS15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



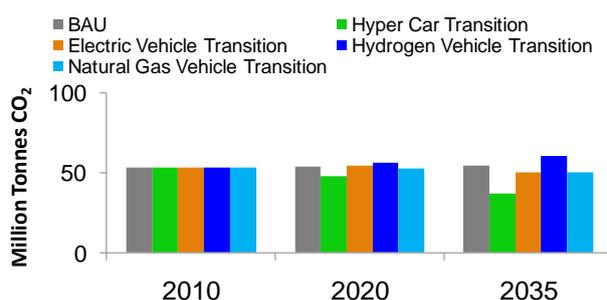
Source: APERC Analysis (2012)

Figure AUS16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Australia, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emission reduction, with an emission reduction of 33% compared to BAU in 2035. This is probably because hyper cars do better in economies like Australia where coal is more likely to be the marginal source of electricity generation. To facilitate fair comparisons, the Electric

Vehicle Transition scenario assumes no additional non-fossil electricity. The Electric Vehicle Transition scenario would rate second, offering a reduction of 9% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario offers emission reductions of 8%, while in the Hydrogen Vehicle Transition scenario, emissions increase by 11% compared to BAU. This is likely due to the emissions associated with converting natural gas to hydrogen to fuel these vehicles.

**Figure AUS16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# BRUNEI DARUSSALAM

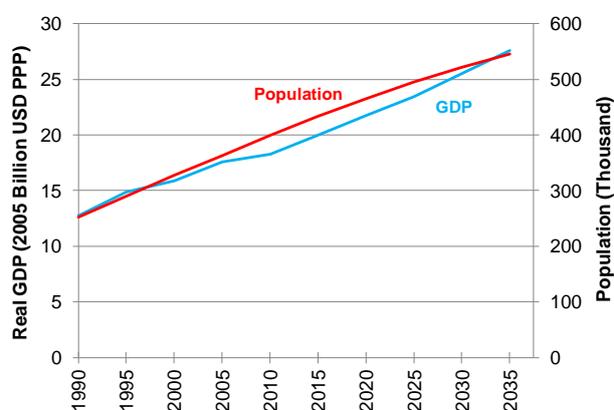
- *Brunei Darussalam has low GDP growth, but high macroeconomic stability.*
- *The economy is highly dependent on LNG and oil exports. The government's efforts to encourage diversification have met with limited success. This is set to change with the introduction of downstream oil and gas industries planned for the first half of the forecast period.*
- *The development of energy-intensive industries is expected to drive final energy demand in Brunei Darussalam, which is projected to increase by 39% from 2010 to 2035, reaching 1.7 Mtoe in 2035.*

## ECONOMY

Brunei Darussalam is located on the north-west coast of the island of Borneo. It has a coastline of about 161 kilometres along the South China Sea and a land area of 5765 square kilometres, of which 75% is covered by primary forest. The economy is characterized by hilly lowlands in the west, rugged mountains in the east, and a swampy tidal plain along the coast. The climate is equatorial, with an average temperature of 28°C, high humidity, and heavy rainfall that ranges from 2500 mm to 7500 mm annually. The economy's only neighbour is the Malaysian state of Sarawak, which separates Brunei Darussalam into two parts.

Brunei Darussalam is a small economy with a total population of 423 000 in 2011, of which 27% were foreigners (DEPD, 2012, p. 4). The economy's population is projected to grow at an average annual rate of 1.3% over the forecast period, with the total population reaching about 550 000 by the year 2035. According to the United Nations, 75.6% of the population was urbanized in 2010; this figure is projected to increase to 80.4% by 2035 (United Nations, 2011).

**Figure BD3: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

The majority of the population is concentrated in the capital, Bandar Seri Begawan, and in the oil refining area of Seria in the west. The remaining areas

are sparsely populated and largely undisturbed. The economy is wealthy and capable of maintaining a welfare state that provides free higher education and healthcare to its citizens, and subsidized housing, food and fuel.

In 2009, Brunei Darussalam achieved a nominal GDP of USD 17.7 billion (in 2005 USD PPP) and a GDP per capita of USD 45 158, which is one of the highest in the world. Brunei Darussalam's GDP is projected to grow at a modest average annual rate of 1.7% over the outlook period, reaching USD 27.6 billion in 2035. Given the projected 1.3% average annual population growth, GDP per capita will remain high, increasing by about 10% to reach nearly USD 50 563 per capita by 2035.

The oil and gas sector is the backbone of Brunei Darussalam's economy, accounting for 67.7% of GDP and 95.6% of total exports in 2011 (DEPD, 2012, p. 8). Brunei Darussalam is the fourth-largest oil producer in South-East Asia and the ninth-largest exporter of liquefied natural gas (LNG) in the world (BEDB, 2011). The economy's non oil and gas sectors include agriculture, forestry, fishing, aquaculture and banking.

There is a rising awareness the economy is depleting its natural resources and subsequently it needs to diversify away from its over-reliance on upstream oil and gas production. The Wawasan Brunei 2035 (referred to here as the Vision Brunei 2035) formulates Brunei Darussalam's plans to upskill the labour force, reduce unemployment, strengthen the banking and tourism sectors, and widen the economic base beyond oil and gas by 2035 (BEDB, 2011). For the short term, the National Development Plan 2007–2012 supports the Vision Brunei 2035 by allocating BND 9.5 billion (around USD 6.6 billion) for 826 programmes and projects to strengthen the economy's human resources base, social services and infrastructure, and to support the development of competitive industries. Priority industries are finance, hospitality, agriculture, halal products (which includes food, pharmaceuticals and

cosmetics) and software development (APERC, 2009).

One of the key initiatives under the Vision Brunei 2035 is to designate industry cluster-specific sites with supporting infrastructure and facilities. This will facilitate industrial development and promote industrial investments. The first site, established in 2007, was the Sungai Liang Industrial Park (SPARK), designed specifically for downstream petrochemical processing activities. Additionally, 1 trillion cubic feet (Tcf) (28.3 billion cubic meter (bcm)) of natural gas has been allocated for domestic downstream activities over an estimated 20-year span (FGE, 2010).

The first plant built at the SPARK site was a methanol plant developed by the Brunei Methanol Company. The plant began production in May 2010 and is capable of producing 850 000 tonnes of methanol each year. The next project in SPARK is an integrated chemical complex housing six plants that will use part of the allocated 1 Tcf (28.3 bcm) of natural gas as feedstock to produce ammonia, urea, di-ammonium phosphate, ammonium sulphate, melamine and caprolactam. The project is being developed by the Mitsui Consortium and is expected to begin operations in 2015 (Brunei Times, 2011).

The second industrial site is the Pulau Muara Besar (PMB) Island site, designed for the development of oil field support services, such as a marine supply base and fabrication yard, as well as further downstream activities (BEDB, 2012). The anchoring project will be a USD 2.5 billion oil refinery and aromatics cracker project to be developed by the Zhejiang Hengyi Group Co. Ltd. The project is expected to begin operations in 2015, with a production capacity of approximately 135 thousand barrels per day. The first phase will comprise the production of petroleum products such as gasoline, diesel and jet A-fuel, as well as paraxylene and benzene used mainly in textile production (BEDB, 2012). The feedstock for this plant will be locally-sourced crude oil and condensate.

Brunei Darussalam's largest export, after oil and gas, is its manufactured garments. It should be noted the total value of garments exported significantly decreased by about 80% from BND 56.7 million in 2009 to BND 8.2 million in 2010, due to a major trade agreement between the economy and the United States expiring in the same year (DEPD, 2012, p. 8). On the other hand, the economy's first methanol plant began exporting its products in May 2010, and other sectors like the agriculture, forestry and fishery sectors and the services sector showed a healthy growth rate of 3–4% from 2009 to 2010 (DEPD, 2012). This healthy growth in the non oil

and gas sectors is consistent with the economy's efforts towards diversification, and is likely to continue in the short to medium term.

Bruneians enjoy a well-developed transport infrastructure; the quality of roads in Brunei Darussalam has been ranked seventh in Asia and third in South-East Asia (Brunei Press, 2011b, p. E89). The major population centres in the country are linked by a network of about 3127.4 kilometres of road (DEPD, 2012, p. 17). Brunei also has one of the highest car ownership rates in the world, with roughly one car for every 2.09 persons (Brunei Press, 2011a). This can be attributed to the limited public transport system, low import tax, inexpensive car maintenance and low unleaded petrol prices. With 170 000 licensed vehicles using the road network daily, the Brunei Darussalam Government is constantly maintaining, upgrading and extending its road network. In its National Development Plan 2007–2012, the government has allocated BND 568.5 million (USD 464 million) for this purpose (Brunei Press, 2011b, p. E89).

The Brunei International Airport (BIA) handles more than 20 000 flights annually. In 2011, 27 822 flights were recorded, including scheduled, non-scheduled, chartered and military flights (DEPD, 2012, p. 17). Brunei Darussalam's major port is at Muara. In 2011, the port handled a total of a little over 1 million freight tonnes of cargo (DEPD, 2012, p. 17). The port authority is continuing its efforts to attract and encourage more shipping lines to call at the port. The Ministry of Industry and Primary Resources is keen to develop the economy's tourism industry by capitalizing on Brunei Darussalam's rich cultural heritage and pristine natural rainforests. If the Ministry's initiative is successful, it is expected the energy demand for both aviation and maritime transport will increase in the coming years.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Brunei Darussalam owes its current prosperity to its significant natural gas and oil resources. The existing and potential oil and gas reserves lie within the economy's northern landmass and extend offshore to the outer limits of its exclusive economic zone (EEZ). As of 1 January 2012, Brunei Darussalam's proven oil reserves stood at 1.1 billion barrels and its gas reserves were estimated at 13.8 Tcf (390 bcm) (OGJ, 2011). The oil reserves are expected to last about 25 years and the natural gas reserves 40 years. New recovery technologies as well as potential onshore and deepwater fields are expected to add to the lifespan of the reserves.

In 2010, the economy's major oil fields were the onshore Seria-Tali field, with 292 producing oil wells, and the offshore fields Champion (239 producing oil wells) and South West Ampa (152 producing oil wells) (OGJ, 2011). On average, Brunei's oil fields produced 160 000 barrels per day in 2010. Only a small fraction of the oil produced is refined at Brunei Darussalam's sole refinery in Seria, which has a distillation capacity of 15 000 barrels per day. The main products are motor gasoline, diesel oil and dual-purpose kerosene. These outputs are used almost exclusively for domestic consumption. The rest of Brunei Darussalam's crude oil is exported and refined elsewhere.

Brunei Darussalam's most prolific natural gas field is also its oldest offshore field, the South West Ampa field. It holds more than half of the economy's total natural gas reserves. Other sources include the gas wells in the Fairley, Gannet and Maharajalela-Jamalulalam fields (OBG, 2009). The production from these fields is piped to the Brunei LNG Plant in Lumut to be liquefied. Most of the LNG produced is exported to Japan and Korea (Brunei LNG, 2010).

Brunei Darussalam has an installed electricity capacity of 894 MW that produced 3723 GWh of electricity in 2011 (DEPD, 2012, p. 19). Given the abundance of natural gas available in the economy, almost all of its installed electricity capacity is natural gas-fired. The only exceptions are the diesel power station at Belingus and the demonstration 1.2 MW Tenaga Suria Brunei (TSB) solar energy plant. The solar plant is the largest-scale photovoltaic project in South-East Asia, and is capable of producing 1344 MWh of electricity each year (OBG, 2011). Brunei Darussalam has significant solar, hydro and biomass potential, but it has no concrete plans for exploiting this potential on a large scale due to environmental and cost constraints. Instead, in the near future, the economy will concentrate on reducing its energy intensity through energy efficiency and conservation initiatives.

As reported in the Brunei Key Indicators 2011, 99.9% of the population is already connected to the electricity grid, while the remaining 0.1% is served by stand-alone generators (DEPD, 2012, p. 19). The transmission network is divided into three separate grids, namely the Brunei-Muara network, the BPC network and the Temburong District network. The three grids are operated by two different utilities, the Department of Electrical Services (DES) and the Berakas Power Company Private Limited (BPC). The National Development Plan 2007–2012 proposes that all three of the economy's power grids are interconnected by 2012.

## ENERGY POLICIES

Brunei Darussalam's energy policy is centred on its oil and gas industries. In 1981, the Oil Conservation Policy was introduced when oil production peaked at 261 000 barrels per day in 1979. The policy aimed to prolong the life of the economy's oil reserves by rationalizing its oil output. As a result, production gradually dropped to around 150 000 barrels per day in 1989. In November 1990, the government reviewed the policy and removed the production ceiling, resulting in the production of 219 000 barrels per day by 2006 (APEREC, 2009). In 2011, oil production averaged 166 000 barrels per day (DEPD, 2012, p. 11).

In 2000, the Brunei Natural Gas Policy (Production and Utilization) was introduced. The policy aimed to maintain gas production at year-2000 levels to adequately satisfy export obligations, to open new areas for exploration and development, and to encourage increased exploration by new and existing operators. Under the policy, priority is always given to domestic gas use, especially for electricity generation.

Brunei Darussalam has set an economy-wide target to reduce its energy intensity by 45% by 2035, with 2005 as the base year. To ensure the 45% reduction target is met, Brunei Darussalam has identified a number of action plans for the generation, residential, industry, government and transport sectors. These action plans are designed to improve energy efficiency performance in these five sectors between 2010 and 2030. Some of the action plans identified include: restructuring the residential electricity tariff structure; improving the efficiency of new and existing power plants; formulating an economy-wide standard and labelling for air conditioning and lighting systems; initiating energy management programmes in government and industrial buildings; and introducing energy efficient vehicles like hybrid and electric vehicles into Brunei Darussalam's automotive market (APEREC, 2012). These action plans will be formalized in the Energy White Paper to be published in early 2013.

Brunei Darussalam implements five-year economic development plans known as National Development Plans that also serve as guidance for its energy policies. Currently, the ninth National Development Plan 2007–2012 is in force. In line with this plan, the economy has launched a long-term development plan, the Vision Brunei 2035. The Vision aims to make Brunei Darussalam, by 2035, a nation which will be widely recognised "for the accomplishment of its educated and highly skilled people as measured by the highest international

standards; quality of life that is among the top 10 nations in the world; and a dynamic and sustainable economy with income per capita within the top 10 countries in the world” (DEPD, 2008).

In May 2005, His Majesty the Sultan and Yang Di-Pertuan of Brunei Darussalam created the post of the Minister of Energy. The Energy Division at the Prime Minister’s Office was also created, to be responsible for formulating the economy’s energy policy as well as presiding over its energy matters. The Petroleum Unit, that oversees the development of Brunei Darussalam’s natural gas and oil sector, and the Department of Electrical Services, that is tasked with managing and developing its electricity sector, come under this ministry. In 2011, the Energy Division and the Petroleum Unit merged to become the Energy Department under the Prime Minister’s Office.

The Brunei Shell Petroleum Co. Sdn. Bhd. (BSP), jointly owned by the Brunei Darussalam Government and the Royal Dutch/Shell Group of the Netherlands, has been the dominant oil and gas production company in the economy. The only other concessionary is the French multinational oil company, Total E&P Deep Offshore B.V. In 2002, the Brunei National Petroleum Company Private Limited (PetroleumBRUNEI) was empowered to manage Brunei Darussalam’s commercial interests in the oil and gas sector. PetroleumBRUNEI has been granted all mineral rights in eight petroleum exploration blocks, nominee shareholder status in the Brunei Methanol Company Private Limited, and one of its subsidiaries, PB Logistics, is a shareholder in the Brunei Methanol Tanker (BMT).

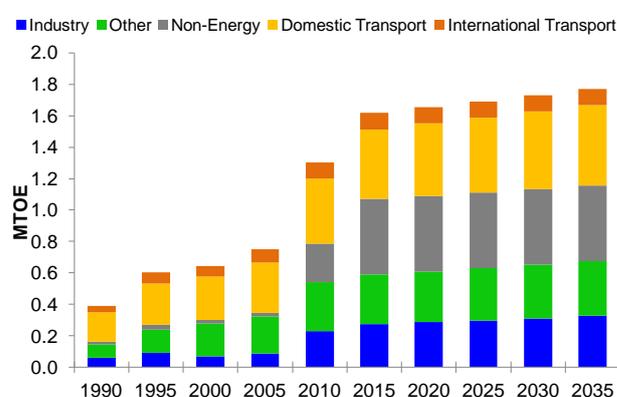
Currently, energy prices are heavily subsidised. Before 2012, the residential electricity tariff was priced at approximately BND 0.06 (USD 0.044) per kWh. A new tariff structure, which came into effect on 1 January 2012, was designed to encourage smart electricity use and to help the poor by rewarding low users and penalising heavy users of electricity. Motor fuel prices remain comparatively low, with petrol prices varying from BND 0.36 (USD 0.26) per litre for regular to a maximum of BND 0.53 (USD 0.38) per litre for premium unleaded (Lawrey and Pillarisetti, 2011). In an effort to address the challenges of increasing demands and depleting resources and to improve energy efficiency performance, the government of Brunei Darussalam has decided to implement progressively increasing electricity tariffs and to adopt European Union equivalent fuel economy regulations. These measures will be formalized in the economy’s Energy White Paper to be published in early 2013.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

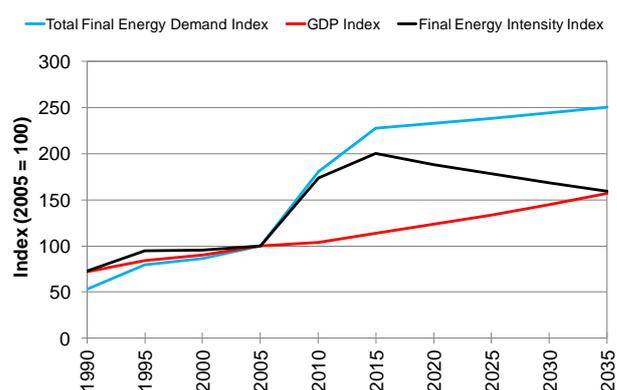
The total final energy demand for Brunei Darussalam is projected to almost double from 0.9 Mtoe in 2009 to 1.7 Mtoe in 2035. The industry and non-energy sectors begin to take up a much larger portion of final energy demand from 2010 onwards, compared to an almost negligible share before 2010. This is due to the methanol plant in SPARK beginning production in that year. The methanol plant will require massive amounts of natural gas as fuel, resulting in gas taking a large chunk of oil’s dominant share of final energy consumption. By 2035, oil will still account for the largest share (46%), followed by gas (35%), electricity (19%) and NRE (0.6%).

Figure BD4: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure BD3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Under BAU scenario, Brunei Darussalam’s final energy intensity is expected to increase by 60% between 2005 and 2030. This increase will be driven primarily by a growing demand for energy for the new industries in the industry and non-energy sectors. The energy efficiency action plans and

measures to be initiated in the Energy White Paper may help to alleviate some of this increase.

### Industry

The changes in the final energy demand depend on two aspects: the expansion of the energy-intensive industry sector and the start of methanol production at the SPARK site in 2010. Other industries proposed for the SPARK and Pulau Muara Besar industrial sites are not considered in this analysis—they are still in the early stages of planning and their definite time of entry has yet to be established.

The final energy demand for industry in Brunei Darussalam is projected to increase by 41% from 2010 to 2035, reaching 326 kilotonnes of oil equivalent (ktoe) by 2035. The industry sector's energy demand will be for oil (58%), electricity (22%) and gas (20%).

### Transport

The domestic transport sector's demand for energy is projected to continue to increase during the forecast period, reaching 512 ktoe in 2035. Petroleum products are expected to remain the dominant transport energy source, but their growth will slow with the expected improvements in vehicle fuel efficiency.

### Other

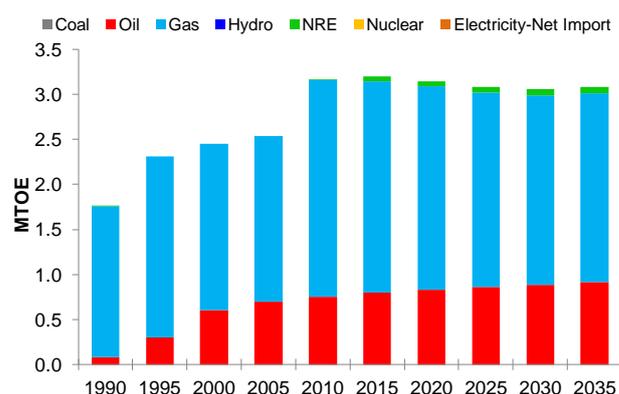
The final energy demand in the 'other' sector, which represents the residential, commercial and agricultural sectors, is projected to increase by 12.5% from 2010 to 2035, reaching 349 ktoe by 2035. This will be driven mostly by the residential sector. Electricity consistently holds a two-thirds share of energy demand for the 'other' sector throughout the outlook period.

## PRIMARY ENERGY SUPPLY

Brunei Darussalam's primary energy supply is expected to remain fairly constant at about 3 Mtoe over the forecast period. Natural gas and oil will remain the dominant supply fuels for primary energy with small contributions from solar and biomass.

Natural gas production and oil production are forecasted to gradually decrease over the 2010–2035 period due to maturing reserves and the increasing complexity of resource exploration in the economy. Since domestic consumption is modest and priority is given to domestic use, it is expected that the decrease in production will be reflected in the amount of oil and gas exported each year. There is no coal production or coal consumption in this economy.

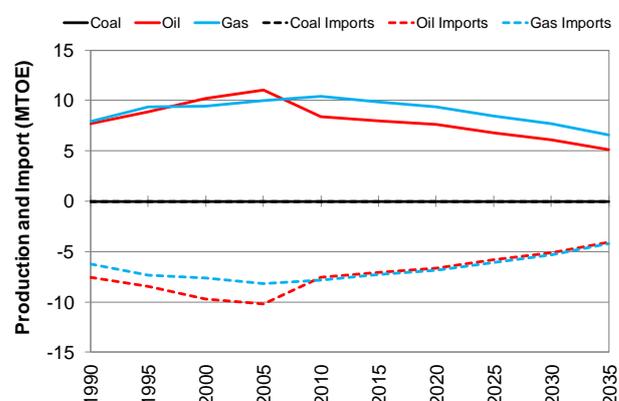
Figure BD4: BAU Primary Energy Supply



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure BD5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)

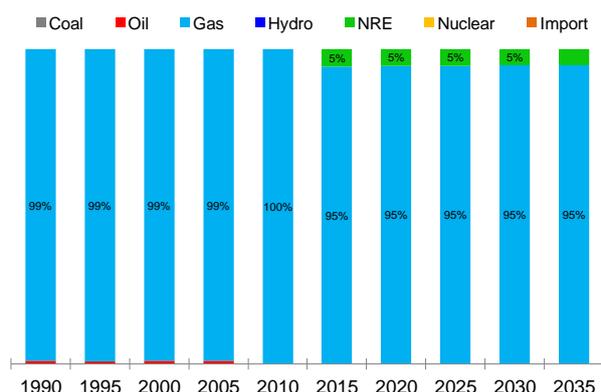
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

## ELECTRICITY

Brunei Darussalam is projected to continue to rely heavily on natural gas for electricity generation. The economy is expected to improve its conversion efficiency by replacing the existing single-cycle power plants with combined-cycle gas units and by ensuring all new power plant installations have over 45% efficiency (APERC, 2012).

Brunei Darussalam will also begin to diversify its energy resources by taking advantage of its available new renewable energy (NRE) potential. The economy already has a 1.2 MW solar power plant and will continue to develop more solar capacity during the outlook period. Another form of NRE capacity that will likely be introduced is biomass generation, using landfill gas as fuel. By 2035, NRE's contribution to total power generation will increase to 5%, compared to zero in 2009.

Figure BD6: BAU Electricity Generation Mix

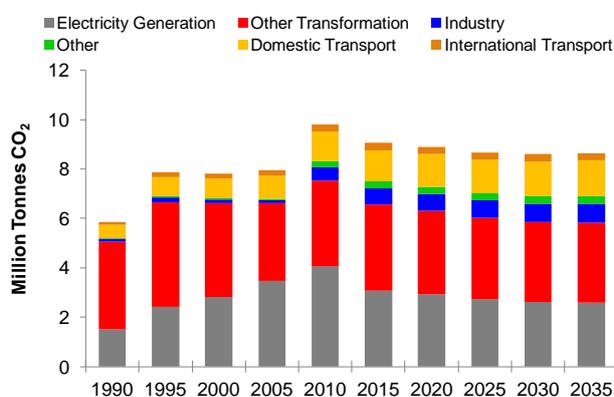


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

### CO<sub>2</sub> EMISSIONS

Brunei Darussalam’s annual CO<sub>2</sub> emissions from fuel combustion are projected to begin to decrease from 2010 onwards, reaching about 8.65 million tonnes of CO<sub>2</sub> in 2035. This compares to 5.9 million tonnes in 1990 and 8.0 million tonnes in 2005. The sudden increase in CO<sub>2</sub> emissions from the industry sector in 2010 can be attributed to production starting at the SPARK methanol plant. Improvements in power generation efficiency will contribute to reducing the CO<sub>2</sub> emissions from this sector over the next 25 years.

Figure BD7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table BD1 shows that from 1990 to 2005, the growth in CO<sub>2</sub> emissions was underpinned by growing GDP, but from 2010 to 2035, total change in CO<sub>2</sub> emissions will show a declining trend, driven by declining trends in CO<sub>2</sub> intensity and energy intensity.

Table BD1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.5%	-0.8%	-0.7%	-0.5%	-0.5%
Change in Energy Intensity of GDP	0.3%	3.7%	-0.7%	-0.9%	-1.7%
Change in GDP	2.2%	0.8%	1.5%	1.5%	1.7%
Total Change	2.1%	3.7%	0.1%	0.1%	-0.6%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

As a major oil and gas producer and exporter, Brunei Darussalam’s economic and energy security is assured. Unfortunately, based on historical data, this abundance of wealth and resources has not created an environment conducive to energy efficiency and conservation measures.

Brunei Darussalam’s Vision Brunei 2035, published in 2008, and the upcoming Energy White Paper, to be published in 2013, outline environmental policy directions and initiatives designed to minimize environmental impacts and to conserve existing oil and gas resources. These measures may help Brunei Darussalam meet its challenges to maintain economic and energy security as well as to improve environmental sustainability.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

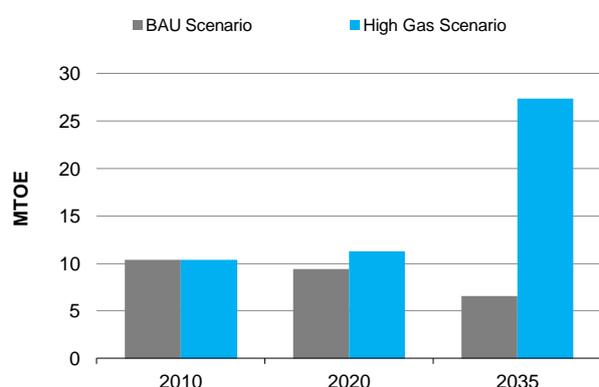
#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario for Brunei Darussalam assumed the production increase shown in Figure BD8, which equals 315% by 2035. This is based on the draft for Brunei Darussalam’s Energy White Paper, in which the economy proposes to explore deepwater offshore commercial blocks more aggressively and to review the potential of developing small and marginal fields that have previously been deemed infeasible. The success of these proposed initiatives will certainly increase Brunei Darussalam’s gas production. The Energy White Paper provides estimates for the potential increase in gas production,

and these estimates were adopted for the High Gas Scenario for this economy.

**Figure BD8: High Gas Scenario – Gas Production**



Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. Since domestic power generation in Brunei Darussalam is almost fully gas-based, the additional gas production will likely be exported as LNG. As a result, no change is expected in the economy’s electricity generation mix or in its CO<sub>2</sub> emissions. Thus, Figures BD9 and BD10 are not included for this economy.

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

The alternative urban development scenarios evaluate potential transport energy savings from urban planning by modelling the relationship between travel distance, vehicle efficiency and vehicle ownership. Unfortunately, there is not sufficient data on urban land use available for Brunei Darussalam to run this scenario. Figures BD11–BD13 are therefore not included for this economy.

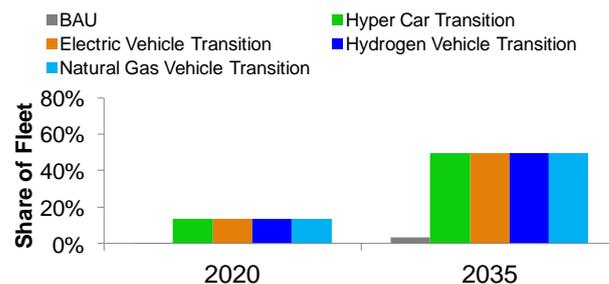
**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’.

The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure BD14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035, the share of the alternative vehicles in the fleet reaches around 50% compared to about 3% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 50%, compared to about 97% in the BAU scenario.

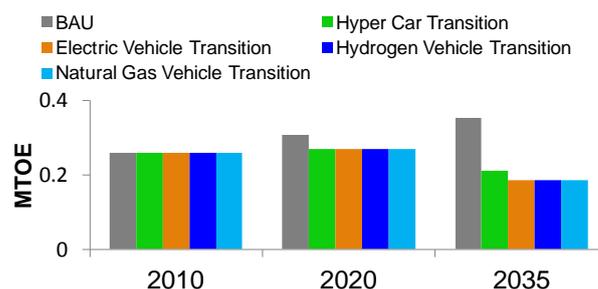
**Figure BD14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure BD15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 47% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 39% by 2035—even though these highly-efficient vehicles still use oil.

**Figure BD15: Virtual Clean Car Race – Light Vehicle Oil Consumption**

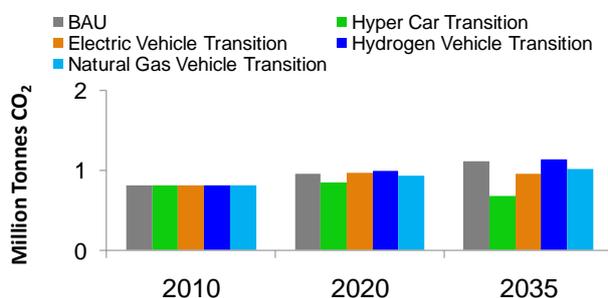


Source: APERC Analysis (2012)

Figure BD16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption,

since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure BD16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Brunei Darussalam, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reduction, with an emissions reduction of 39% compared to BAU in 2035. Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels; namely electricity for electric vehicles, hydrogen for hydrogen vehicles and natural gas in natural gas vehicles. In Brunei Darussalam virtually all electricity generation comes from gas combustion, thus the additional demand for electricity and hydrogen generation would require more gas combustion, which in turn would produce more CO<sub>2</sub> emissions.

The runner-up in this race is the Electric Vehicle Transition scenario offering a 14% emissions reduction compared to BAU, followed by the Natural Gas Vehicle Transition scenario (8%). The Hydrogen Vehicle Transition scenario offers the least benefit, producing 3% more emissions compared to BAU in 2035.

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# CANADA

- *Canada's commitment to energy efficiency through its policies will help the economy to keep its overall energy demand moderate in the long term.*
- *Canada will remain the world's largest oil sands producers, one of the largest shale gas producers, and a major energy exporting economy.*
- *Annual CO<sub>2</sub> emissions from fuel combustion are projected to increase by 20% over the outlook period. This can be attributed to Canada's projected strong growth in the resources sector fuelling economic growth and activity.*

## ECONOMY

Canada's land area is the second largest in the world, after Russia. The economy is located in the northern part of North America, and has a widely varied climate, from temperate in the south to sub-arctic and arctic in the north. Canada's geography and climate contribute to its high energy consumption (about four times the APEC average) (APEREC, 2009). The economy's high energy use is due in part to the demand for the transportation fuels required to travel its vast distances, and the space and water heating needed to cope with its cold weather.

Canada is made up of a Federal Government, 10 provincial governments and three territories. Roughly 90% of the land in Canada is Crown land (land held for the monarchy). The majority of this land is owned by the relevant provincial government. Under the Canadian Constitution, the provinces have ownership over the natural resources that lie within their provincial boundaries. Provincial governments manage the pace of energy resource development within their jurisdiction. Federal jurisdiction applies to territories north of 60 degrees, aboriginal and offshore frontier areas. Offshore areas are jointly managed by federal/provincial authorities. The federal government also regulates interprovincial and international energy trade.

Canada was demonstrating solid economic growth before the onset of the global recession in 2008 and its continuation into 2009. Between 1990 and 2009, GDP increased at an average of 2.4% per year. Although there was negative growth in Canada's economy in 2009, GDP is expected to recover, and to grow at an average of 2.4% per year over the outlook period.

The affluence of this economy translates into a high standard of living. Canada's car ownership rate is high for the APEC region. In 2009, there were nearly 21 million registered vehicles on the road—96% of these vehicles were up to 4.5 tonnes (light vehicles) (Statistics Canada, 2010a). Given the urban

sprawl and the well constructed road network, automobiles are the dominant means of intercity passenger travel. Compared to other industrialized economies, the public transport system is less extensive and its market share is primarily limited to the larger cities. However, compared to its neighbour the United States (US), Canada's public transport is better funded and of a higher quality.

Canada is an advanced industrialized economy with a substantial services sector. Unlike many other developed economies, Canada's economy has a large natural resources producing component. This includes oil and natural gas, minerals and metals mining, forestry, and agricultural sectors. The mining and oil and gas extraction industries alone accounted for about 4.5% of GDP in 2010 (Statistics Canada, 2012).

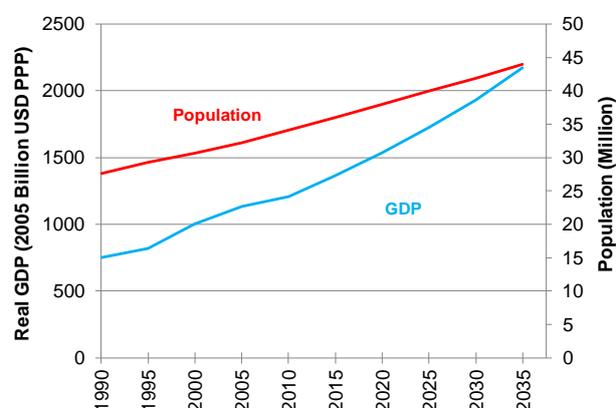
Canada is moving toward a knowledge-based economy: the service industry employs three-quarters of the workforce and generated 72% of GDP in 2010. Manufacturing makes up 13% of GDP—this includes major industries producing transport equipment, food, chemicals, fabricated metal products, and machinery. Canada's economy is closely tied in with the US economy: in 2010, the US accounted for 73% of Canada's exports and 63% of its imports (Statistics Canada, 2012).

There is an extensive freight rail network across the southern part of Canada. Given Canada's large size, long distance trucking is quite common. Along with this, Canada has many sea ports along its Pacific Ocean and Atlantic Ocean coastlines.

In 2009, Canada had a population of 33.7 million, with the majority of the population living in urban areas. Given Canada's climate, most of the population lives in the southern region, avoiding the sparsely populated northern region that suffers from very cold temperatures. The population is estimated to reach 44.3 million by 2035, growing at an average of 1% per year. The median age of the Canadian population has been increasing over the last

three decades: at 1 July 2010 the median age was 39.7 years. In the long term, this could have labour force implications (Statistics Canada, 2011, p. 352).

**Figure CDA1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

## ENERGY RESOURCES AND INFRASTRUCTURE

Canada is richly endowed with natural resources: oil, natural gas, coal, and uranium in its western provinces and huge hydropower resources in Quebec, British Columbia, Newfoundland, Ontario, and Manitoba. It also has offshore oil and gas reserves near Nova Scotia and Newfoundland. Installed electricity generation capacity was 130.5 gigawatts (GW) in 2010 (Statistics Canada, 2010b). Canada is the world's fifth-largest energy producer (behind the United States, Russia, China and Saudi Arabia). It is a major energy exporter, being the most important source for US energy imports (EIA, 2009).

Canada is the world's third largest hydroelectricity producer, after China and Brazil. Even though it is greatly used, there is still undeveloped hydropower potential available, more than double the current capacity, across all provinces and territories (technically, the potential for an additional 163 000 MW). There is roughly 25 000 MW of additional capacity in various planning stages (Irving, 2010).

Canada is endowed with huge oil potential. At 173 billion barrels, Canada's proven oil reserves are the third largest in the world, after Saudi Arabia and Venezuela. The oil sands account for 98% of Canada's oil reserves. 'Proven oil reserves' are the estimated remaining volume of oil that is economic to recover with current technology. This figure is known through drilling, testing and production.

As of 2011, Canada's remaining technically recoverable oil sands and conventional oil resources

were estimated by the National Energy Board (NEB) at 343 billion barrels. The oil sands account for 90% of these oil resources. 'Technically recoverable oil' is the volume of oil that can be produced, and recovered from the subsurface, if costs are not considered a limiting factor.

There is much potential to add to Canada's proven oil reserves. Presently, non-conventional established oil reserves are only reported for Alberta. However, assessments are still underway to estimate the size of the oil sands bitumen resources in Saskatchewan. In future, Canada's proven oil reserves could grow as some of Saskatchewan's oil sands resources become recognised as proven oil reserves. Furthermore, the Grosmont carbonate formation is estimated to account for 21% of the oil sands resources in-place in Alberta but thus far has not been assigned any value as either a proven oil reserve, or even a technically recoverable resource.

The application of horizontal drilling and multi-stage hydraulic fracturing has given new life to previously low-producing or unproductive conventional oil reservoirs. The development of tight oil resources (also called shale oil) has already reversed the decline of conventional oil production in Canada and the United States. Since tight light oil extraction technology is still in its early stages of development in Canada, the ultimate impact on the resource potential is unclear. However, the successful development of Canada's tight oil resources could lead to a significant increase in the size of conventional oil reserves.

Canada is seeking to expand its oil pipeline infrastructure to enable it to export its growing oil production. In December 2011, the National Energy Board approved the Bakken Pipeline project. The pipeline will extend from Saskatchewan to Manitoba, connecting to the Enbridge Pipelines Inc. mainline system and will serve as a continuous, long-term source of light crude oil supply to the central Canadian and US mid-west markets. This will maintain the long-term competitiveness of refineries in those regions (APERC, 2012). In addition, Enbridge's Northern Gateway pipeline, a 525 000 barrel per day (26 Mtoe/year) project, is currently undergoing regulatory review and Kinder Morgan plans to twin its existing TransMountain pipeline, via a 450 000 barrel per day (22 Mtoe/year) expansion. It intends to seek regulatory approval in 2014 and anticipates the expanded pipeline system could be in service by 2017. These pipelines will enable Canada to expand oil exports to the Asia Pacific region (NRCAN, 2012a).

Globally, Canada is the third largest producer of natural gas (behind Russia and the US) and fourth largest exporter (behind Russia, Norway and Qatar). Canadian natural gas production is expected to rise over the outlook period, driven by growth in unconventional natural gas production (NRCan, 2012a).

Most of the economy's conventional gas resources are located in western Canada. The Canadian Society for Unconventional Resources (CSUR) estimates Canada's marketable natural gas resources (conventional and unconventional gas resources) at 19.9 to 36.8 trillion cubic meters (131 000 to 242 000 Mtoe). These natural gas resources represent hundreds of years of supply. Unconventional natural gas (e.g. shale and tight gas) represents the largest component of Canada's natural gas resources, and most of these resources are located within the Western Canadian Sedimentary Basin. However, there are significant natural gas resources located in eastern Canada within the Utica and Maritime Basins (NRCan, 2012a).

Currently in the North American market, natural gas prices are depressed, largely due to excess supply. The US, like Canada, is rich in shale gas resources and while the US is looking at developing these resources, it is also looking at developing LNG (liquefied natural gas) export terminals, rather than import terminals. Nevertheless, the US (EIA, 2012) projects that Canada will remain a major exporter of natural gas into the US market up to the end of the reference period in 2035.

Canada, too, is looking at building LNG export terminals with proposed sites on the west coast. The development of these terminals will provide Canada with a larger market for its gas—other Asia Pacific economies such as Japan and Korea. There are several LNG terminals proposed for British Columbia:

- Douglas Channel LNG, a partnership between BC LNG Export Co-operative and Douglas Channel Energy Partnership, to liquefy 7.1 million cubic metres/day (2.3 Mtoe/year) of natural gas. The first phase to liquefy 3.5 million cubic metres/day (1.15 Mtoe/year) could be in-service in late 2013 or early 2014;
- Kitimat LNG, a partnership between Apache, EnCana and EOG Resources, to liquefy 36.8 million cubic metres/day (12.1 Mtoe/year) of natural gas, expected to be in-service in 2017;
- LNG Canada, a partnership between Shell, Mitsubishi Corp, Korea Gas Corp. and PetroChina Company Limited, to liquefy

96.3 million cubic metres/day (31.6 Mtoe/year) of natural gas, the first phase of which (48.1 million cubic metres/day or 15.8 Mtoe/year) is expected to be in-service in 2019;

- Two other LNG terminals are proposed for the Port of Prince Rupert in British Columbia, led by Petronas of Malaysia and the British Gas Group.

In oil sands operations in Alberta, natural gas is used to generate electricity and steam. Steam is used for in situ oil production and in the production of hydrogen to upgrade bitumen into synthetic crude oil blends. Gas consumption by the oil sands industry in 2011 was estimated to be approximately 10% of Canada's total natural gas production (NEB, 2011a).

As noted earlier, growing natural gas requirements in North America have prompted a major push in the construction of LNG export facilities on Canada's west coast. On Canada's east coast, the Canaport LNG terminal in Saint John, New Brunswick, began operating in June 2009 and is currently Canada's only operating LNG import facility. However, the focus is now on export terminals given Canada's considerable unconventional gas supply potential, especially in the form of shale gas and tight gas (NRCan, 2011b). Due to the shale gas supply revolution and low North American natural gas prices relative to world markets, almost all import proposals are on hold.

Most of Canada's coal reserves are located in western Canada. The consumption of domestic coal and thermal coal imports are expected to decline in the outlook period, largely due to the phasing out of coal fired power generation by 2015 in Ontario. However, coal production is expected to increase as a result of multiple projects coming online in western Canada, increasing the exportable amount of coal (NEB, 2011b).

Canada continues to be a leading producer of uranium, with nearly one-fifth of world production (9145 tonnes of uranium metal) in 2011. Canada's low-cost high-quality uranium resources are the third largest in the world, after those of Australia and Kazakhstan. As of January 1, 2012 Canada's total recoverable low-cost uranium resources were estimated at 466 300 tonnes of uranium metal. Recent exploration activity is expected to further increase these figures (NRCan, 2012a).

Hydropower dominated electricity generation in 2010 (59%), followed by coal (13%) and nuclear energy (15%). Nuclear generated power is most prominent in the province of Ontario, where it accounted for 54% of electricity generation in 2010.

Ontario has initiated plans to construct two new nuclear plants (1000 MW each). A clear timeline for their completion has not yet been announced. The Point-Lepreau Station in New Brunswick is expected to be back online in 2012. The Government of Quebec recently announced it will not continue with the refurbishment of the Gentilly-2 reactor and instead intends to close the nuclear generating station by the end of 2012 (NRCAN, 2012a).

Canada is a net exporter of electricity. Given the increase in the production of clean and renewable energies, there is potential for significant extra electricity to be available for export. The US is the recipient of Canada's electricity exports. In 2011, Canada's electricity exports to the US totalled CAD 2.03 billion (NEB, 2011).

## ENERGY POLICIES

The Canadian Government has a number of policies that promote energy efficiency and cleaner technologies, boost renewable energy supplies and aim to reduce greenhouse gas (GHG) emissions. Since 2006, the Government of Canada has invested more than CAD 10 billion to reduce greenhouse gas emissions and build a more sustainable environment through investments in green infrastructure, energy efficiency, clean energy technologies and the production of cleaner fuels. As part of the Copenhagen Accord, Canada pledged to set a goal to reduce emissions by 17% from 2005 levels by 2020; this was endorsed again through the Cancun Agreement and is in line with US goals.

The Energy Efficiency Act, which took effect in 1992, has been amended to expand its scope and increase its effectiveness (NRCAN, 2009a). This includes provisions aimed at reducing standby power consumption, which is currently 10% of household electricity use in Canada. Provincial governments are also major contributors to energy efficiency in their respective provinces through the establishment of energy efficient building codes, equipment standards, etc.

Canada's energy policy, including for resource development, is market-based and incorporates a mix of domestic and foreign owned companies. As per the Canadian Constitution, the regulation of mining activities on publicly owned mineral leases falls under provincial or territorial government jurisdiction. Therefore, there is separate mining rights legislation for each of the 13 Canadian jurisdictions except Nunavut (the northern and eastern portions of the former Northwest Territories). Off-shore mineral rights are usually owned by the Canadian Federal Government (NRCAN, 2011b).

Since the signing of Western Accord and the Agreement on Natural Gas Markets and Prices, in 1985, oil and natural gas prices in Canada have been deregulated. The agreements opened up the oil and gas markets to greater competition by permitting more exports, allowing users to buy directly from producers and unbundling production and marketing from transportation services. Oil and gas pipeline networks continue to be regulated as natural monopolies (NRCAN 2009b; NEB 1996).

In most provinces, the electricity industry is highly integrated with the bulk of generation, transmission and distribution services provided by one or two dominant utilities. Although some of these utilities are privately owned, many are Crown corporations owned by the provincial governments. Independent power producers also exist, but rarely in direct competition with a Crown corporation. Exceptions include the provinces of Alberta, which has moved to full wholesale and retail competition, and Ontario, which has established a hybrid system with competitive and regulated elements. Retail electricity prices vary across the provinces, in terms of both their level and the mechanism by which they are set. Within the power sector, Canada has an accelerated capital cost allowance (CCA) program which gives a tax benefit for clean energy generation, allowing 50% CCA for projects that use renewable energy equipment or use fossil fuels efficiently, including co-generation (NEB, 2011). In addition, the federal government has invested CAD 1.5 billion to increase Canada's energy supplies from renewable sources, including solar, tidal, hydro, wind, biomass and geothermal through the ecoENERGY Renewable Initiative.

One policy measure that has proved successful in promoting energy efficiency and creating energy savings is the ecoENERGY Retrofit initiative. The program provided incentives for energy efficiency improvements in low-rise residential housing and in small and medium-sized organizations in the institutional, commercial and industrial sectors. The ecoENERGY Retrofit–Small and Medium Organizations component of the initiative ran from April 2007 to March 2011. This CAD 40 million program provided financial incentives to implement energy retrofit projects in buildings with up to 20 000 square metres of floor space and industrial facilities with fewer than 500 employees. Financial incentives stimulated almost 1300 energy retrofit projects. The ecoENERGY Retrofit–Homes component of the initiative was also launched in April 2007. The four year, CAD 745 million program provided federal grants to property owners for improving the energy efficiency of their homes. In

2011, an additional one-year investment of CAD 400 million was made, which allowed as many as 250 000 homeowners to participate in the programme. In total, ecoENERGY Retrofit–Homes helped over 640 000 Canadians increase the energy efficiency of their homes. Homeowners reduced their energy consumption by an average of 20% for ongoing savings of more than CAD 400 million a year (NRCan, 2012b).

In the transport sector, energy consumption growth rates have decreased in recent times. This could be attributable to federal, provincial and territorial programs that promote alternative fuel supply. These include funding programs that encourage investment in the biofuels industry as well as separate renewable fuel blending mandates. For instance, since 2010, Canada has had a 5% renewable fuel mandate. This mandate was expanded in July 2011 to include a 2% renewable fuel content requirement for diesel fuel and heating oil. Several provincial governments have set their own renewable fuel standards, some of which mandate a higher renewable fuel content, and some of which were implemented before the federal mandatory blending requirements (CRFA, 2010). Due to growing domestic supply, natural gas is also being promoted as a transportation fuel, particularly for medium and heavy duty vehicles in the freight sector.

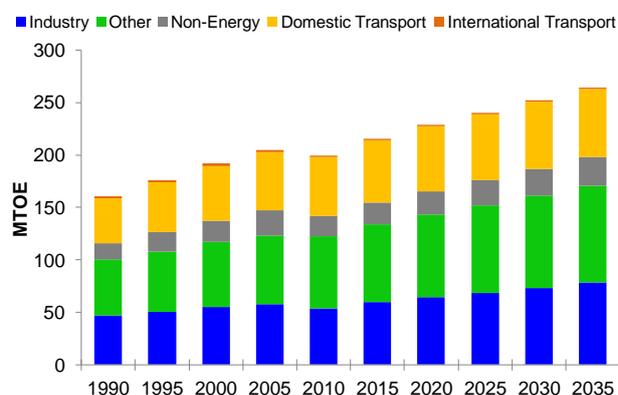
In addition to the above, in October 2011, light-duty vehicle greenhouse gas emission regulations came into force for model years 2011 to 2016, establishing a common Canada–US emissions standard for new vehicles.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow on average 1.1% per year over the outlook period.

Figure CDA2: BAU Final Energy Demand

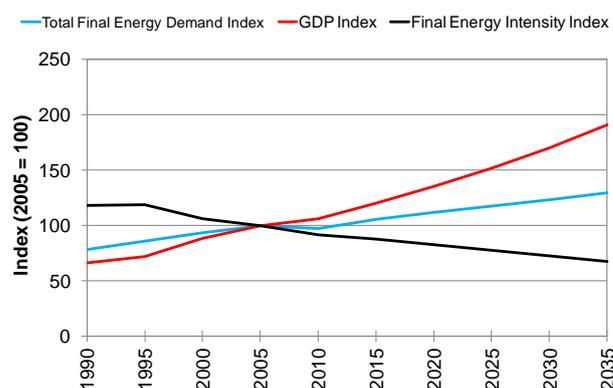


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

A majority of this increase can be attributed to increases in energy consumption across all sectors, especially in the industry and ‘other’ (residential, commercial and agricultural) sectors.

Despite this small increase in final energy demand, final energy intensity (Figure CDA3) is expected to decline by 32% between 2005 and 2035.

Figure CDA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 1.5% between 2010 and 2035. Much of the energy demand will come from energy intensive industries such as iron and steel, aluminium, cement, chemicals and fertilisers, pulp and paper manufacturing, and oil and gas extraction.

### Transport

On average over the outlook period, Canada’s total transport energy demand (including international transport) is projected to grow by an average of 0.6% per year. This is a much smaller growth rate than between 1990 and 2009, when energy demand for transport averaged 1.3% a year.

To comply with the Federal Government’s greenhouse gas emission policies (such as the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations) it is likely fuel economy will improve over the projection period. In April 2012, the Government of Canada released proposed on-road heavy-duty vehicle greenhouse gas emissions regulations for model years 2014 and beyond. Proposed regulations for new passenger cars and light trucks for the 2017 to 2025 model years are also under development. These regulations combined with the renewable fuel content mandate (discussed above) and an interest in natural gas vehicles for medium to heavy fleet trucks in the western

provinces may bring about change in the types of energy sources demanded within the outlook period.

Conventional gasoline and diesel vehicles will account for most of the light vehicle fleet in the projection period, accounting for 84% of the fleet by 2035, with conventional hybrid gasoline and diesel vehicles accounting for another 5%. The dominant fuel source over the projection period and in 2035 for all domestic transport will be oil.

**Other**

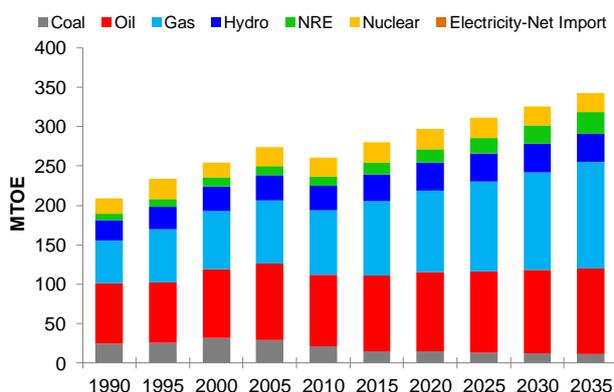
Canada has many policies promoting energy efficiency within the residential and commercial sectors (such as the ecoENERGY Retrofit programs).

However, these efforts will be offset by factors such as the growing population. Energy demand in the ‘other’ sector, which includes residential, commercial, and agricultural demand, is expected to grow on average 1.2% per year over the outlook period. Given Canada’s cold climate, much of the residential and commercial energy use is linked to space and water heating in homes and commercial buildings. Electricity is expected to dominate the fuel mix in this sector throughout the projection period, accounting for 41% of the ‘other’ sector’s energy consumption in 2035, followed closely by gas at 38%.

**PRIMARY ENERGY SUPPLY**

Canada’s primary energy supply between 2010 and 2035 is projected to grow at an average annual rate of 1.1%, in line with the growth in energy demand. Primary energy intensity is projected to decline 34% between 2005 and 2035.

*Figure CDA4: BAU Primary Energy Supply*

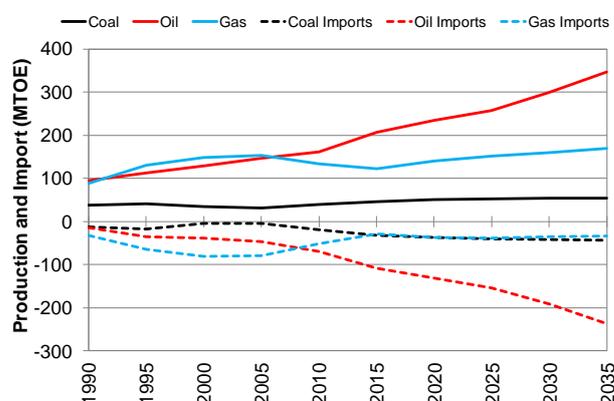


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

The primary supply of oil is projected to increase by 19% between 2010 and 2035, while gas production is projected to increase 27%. Conventional oil and gas production is expected to decline, while increases in production from

unconventional resources (especially oil sands, tight oil, and shale gas) are expected to more than compensate (NEB, 2011a).

*Figure CDA5: BAU Energy Production and Net Imports*

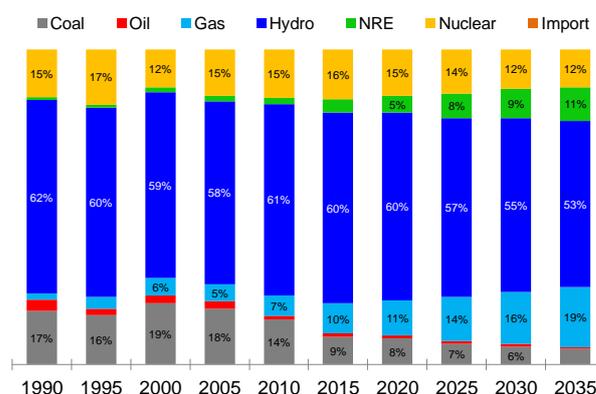


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**ELECTRICITY**

Hydropower will remain Canada’s dominant source of electricity generation throughout the outlook period. After hydropower, gas is expected to be the largest contributor. In 2035, gas will account for 19% of the generation mix, an increase in share of 12% from 2010. This increase will be driven by higher gas production, and a significant reduction of coal use in electricity generation. The reduction in coal use is partly in response to combined efforts by the federal and provincial governments to reduce reliance on coal-fired electricity generation, especially Ontario’s coal phase-out policy and the recently released federal regulations for reducing greenhouse gas emissions from the coal-fired electricity sector.

*Figure CDA6: BAU Electricity Generation Mix*



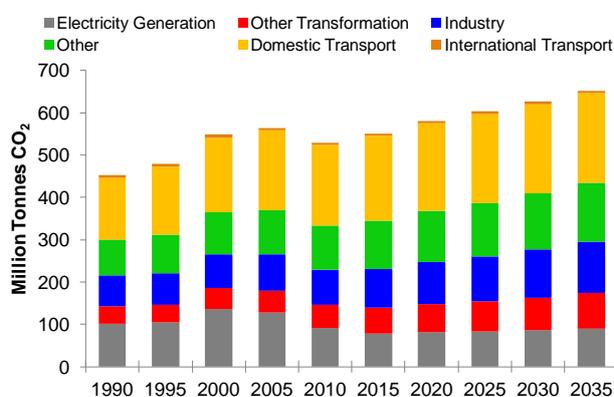
Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**CO<sub>2</sub> EMISSIONS**

Over the outlook period Canada’s total CO<sub>2</sub> emissions from fuel combustion are projected to increase by 23% from 2010 to 2035, to reach

652.2 million tonnes. By fuel, most of the increase in emissions can be attributable to gas, closely followed by oil. By sector, emissions from electricity generation are projected to decline as a result of reductions in coal-fired generation, while emissions in other sectors will continue to grow.

Figure CDA7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

Table CDA1 shows that the growth in emissions that would have otherwise resulted from Canada’s GDP growth are partly offset by reductions in the energy intensity of GDP and reductions in the CO<sub>2</sub> intensity of energy. Reductions in the energy intensity of GDP include improved energy efficiency and shifts to less energy-intensive industry. Reductions in the CO<sub>2</sub> intensity of energy include reductions in coal generation and increases in renewable energy generation.

Table CDA1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
Change in Energy Intensity of GDP	-1.0%	-2.2%	-1.4%	-1.4%	-1.2%
Change in GDP	2.8%	1.2%	2.2%	2.2%	2.4%
Total Change	1.5%	-1.3%	0.4%	0.5%	0.8%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, Canada’s opportunities as an energy exporting economy appear assured. The global demand for oil from secure sources and for natural gas, which has much lower CO<sub>2</sub> emissions than coal, is likely to grow over the Outlook period. Canada has abundant resources of both unconventional oil and unconventional gas, and should be in a good position to help meet this demand. It is, however, important to recognize that there is growing public concern over the environmental risks of unconventional oil and unconventional gas development. These concerns will need to be addressed through enlightened

regulation if oil and gas development is to win the public confidence it will need for Canada to achieve its potential.

### ALTERNATIVE SCENARIOS

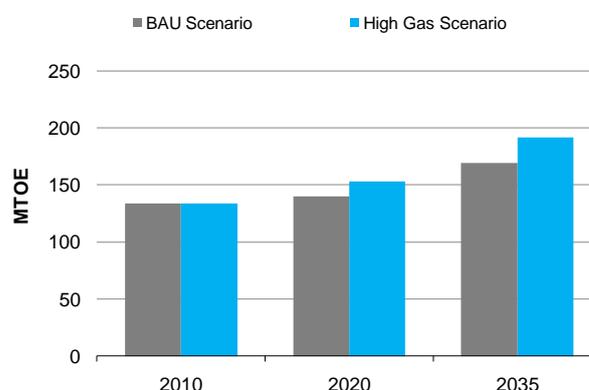
In order to address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

#### HIGH GAS SCENARIO

To understand the impacts that higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario production for Canada assumed a production increase of 13.2% by 2035 compared to BAU, as shown in Figure CDA8. This assumption is based on Canada’s prospective unconventional and conventional gas reserves. As noted above, even under the BAU scenario gas production is expected to increase significantly over the outlook period. Under the alternative scenario, it is assumed that opposition to some gas development projects can be overcome through more intensive engagement with stakeholders, and that the sometimes cumbersome and lengthy approvals processes will be streamlined to allow more gas projects to move ahead quickly.

Figure CDA8: High Gas Scenario – Gas Production



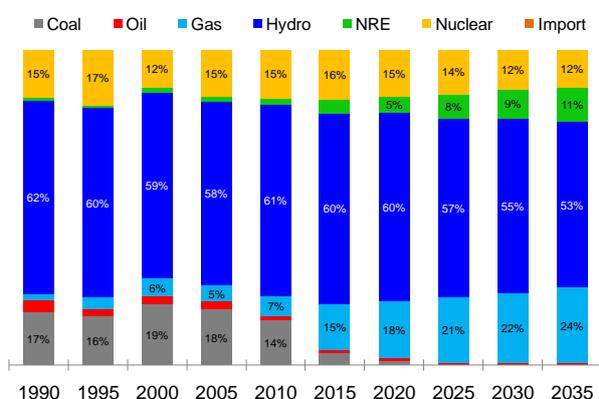
Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also

on the gas market situation in the APEC region. While some of Canada’s additional natural gas will be consumed domestically, it is likely that much will be exported. While currently there are no operational LNG export terminals in Canada, project proposals are under consideration and are assumed to come to fruition under the High Gas Scenario. There should be significant demand for natural gas in Asian economies such as China, Japan, and Korea.

The additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure CDA9 shows the High Gas Scenario Electricity Generation Mix.

**Figure CDA9: High Gas Scenario – Electricity Generation Mix**

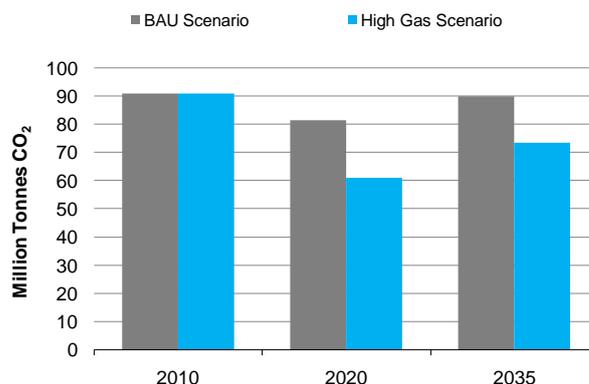


Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

This graph may be compared with the BAU scenario graph shown in Figure CDA6 above. The gas share is 5% higher in 2035 compared to the BAU case, because coal has a 5% market share in the BAU case, the increased gas production thus displaces coal in power generation.

Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by a significant 24% in 2035. The reduction in emissions is comparatively large in percentage terms because the majority of Canada’s electricity generation is from hydro and has no emissions. Figure CDA10 shows this CO<sub>2</sub> reduction.

**Figure CDA10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



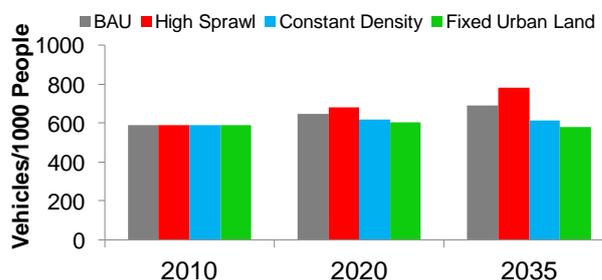
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CDA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. It can be seen that better urban planning is likely to prove beneficial in Canada since under a High Sprawl scenario, vehicle ownership is projected to increase by 13% in 2035 compared to the BAU scenario, whereas under the Constant Density and Fixed Urban Land scenarios vehicle ownership declines 11% and 16%, respectively, compared to the BAU scenario.

**Figure CDA11: Urban Development Scenarios – Vehicle Ownership**

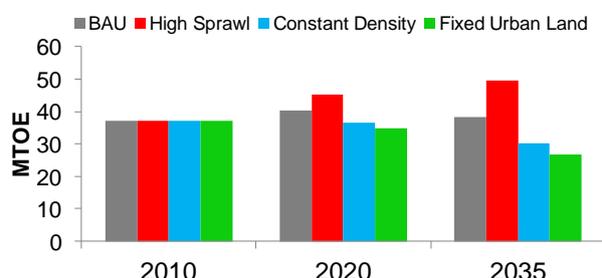


Source: APERC Analysis (2012)

Figure CDA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Similar, but larger, effects than those seen in figure CDA11 can be seen in figure CDA12, since urban planning affects not only vehicle ownership, but also the distances driven.

Oil consumption is projected to increase 29% in 2035 under a High Sprawl scenario compared to the BAU scenario, whereas oil consumption is projected to decline 21% and 31% under the two other scenarios.

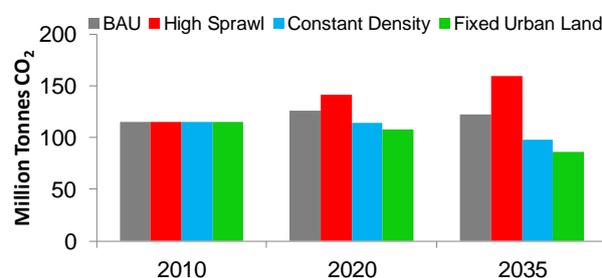
**Figure CDA12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure CDA13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is the same in percentage terms as the impact of urban planning on oil consumption, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure CDA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

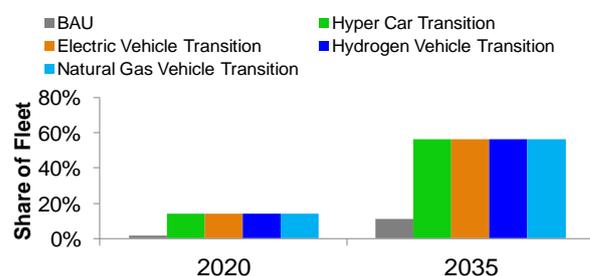
**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CDA14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 57% compared to about 11% in the BAU scenario. The share of conventional vehicles in the fleet is thus only

about 43%, compared to about 89% in the BAU scenario.

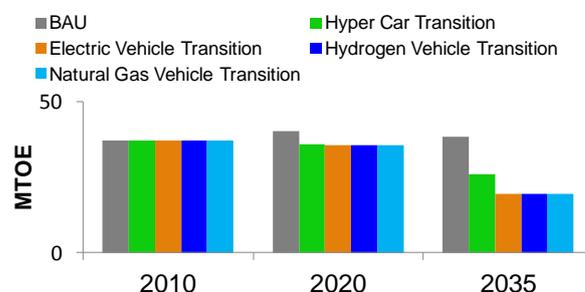
**Figure CDA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure CDA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 34% by 2035—even though these highly-efficient vehicles still use oil.

**Figure CDA15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



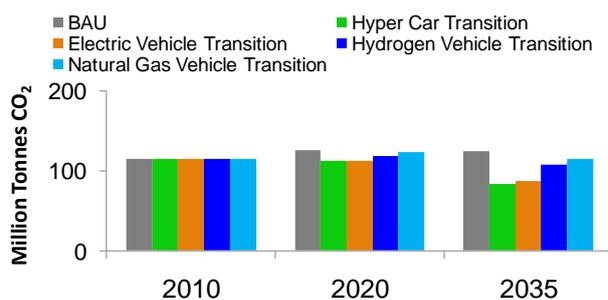
Source: APERC Analysis (2012)

Figure CDA16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, for the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Canada, the Hyper Car Transition scenario is the winner in terms of CO<sub>2</sub> emission reduction, with an emission reduction of 33% compared to BAU in

2035. The Electric Vehicle Transition scenario does almost as well, reducing emissions 30% compared to BAU in 2035, reflecting the fact that, in Canada, relatively low-emission natural gas is assumed to be the marginal source of electricity generation. A Hydrogen Vehicle Transition scenario would reduce emissions by 13% compared to BAU in 2035, while the Natural Gas Vehicle Transition scenario would reduce emissions by 7% compared to BAU in 2035.

**Figure CDA16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# CHILE

- *Through promotion of energy efficiency and construction of LNG import terminals, Chile has responded in an effective and environmentally responsible fashion to the natural gas crisis of the early 2000s, which was precipitated by Argentina's restrictions on gas exports to Chile.*
- *Looking forward, however, the business-as-usual outlook suggests that Chile will face additional challenges, with CO<sub>2</sub> emissions more than doubling and oil imports rising 72% over the 25-year outlook period.*
- *Chile may have significant shale gas resources; however, further investigation is required to determine its economic viability there.*

## ECONOMY

Chile is one of three Latin American members of APEC. The economy lies in South America, with Peru to the north and Bolivia and Argentina to the east. It is 4300 kilometres long and on average 175 kilometres wide; the total land area is 756 950 square kilometres. Chile is divided into 15 regions, which form the economy's first level of administration. Each region is headed by a governor appointed by the President. Regions are divided into provinces (the second level of administration), also each headed by a governor appointed by the President. There are 54 provinces in total. Provinces are further divided into communes, which are governed by municipalities.

Chile has a greatly varied climate, covering at least seven major climatic subtypes. Temperatures are influenced by oceanic currents: in the south and centre, the Antarctic current produces cooler temperatures, while towards the north temperatures rise due to the effect of tropical currents. Average temperatures in central Chile range between summer peaks of 20°C and winter lows of 8°C. The climatic diversity causes regional differences in energy consumption patterns, such as use of air conditioning in the north, compared to demand for heating in the south.

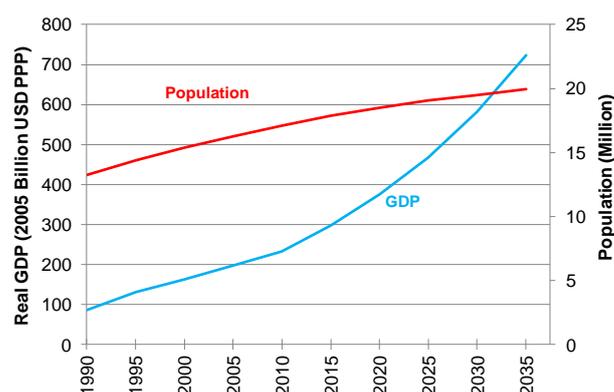
Chile's population is projected to grow at an average annual rate of 0.6% over the outlook period, reaching over 20 million by 2035. Almost all of the 2035 population (99%) are expected to be living in urban areas—mainly in big cities such as Santiago, Valparaiso–Viña del Mar and Concepción.

In 2010, GDP per capita was USD 13 644 (in 2005 PPP) and during the outlook period, Chile's GDP growth is expected to be moderate, with an average annual growth rate of 4.6%. GDP in 2035 is estimated at USD 724 billion at 2005 USD PPP (or USD 36 259 per capita). This assumes continued expansion of the manufacturing industry, which has been a substantial contributor to Chile's GDP; the

mining sub-sector, specifically copper, is also expected to continue to grow.

Chile's economy is based on five key areas: rich mineral resources, agriculture (which takes advantage of the wide variety of climatic conditions), rich fishing grounds, industry, and financial services. Chile has a market-oriented economy characterized by a high level of foreign trade, with export markets balanced among Europe, South America, North America and Asia. Chile has 25 trade agreements in place (MRE, 2008, p. 18), and is an active participant in international organizations such as the Asia-Pacific Economic Cooperation (APEC), the World Trade Organization (WTO), Southern Common Market (Mercado Común del Sur or Mercosur), European Free Trade Association (EFTA), Central American Common Market (CACM) and Latin American Energy Organization (Olade).

Figure CHL5: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Broken down by economic sectors, Chile's GDP in 2010 was composed of agriculture and mining (21%), manufacturing and industry (22%) and services, transport and communications (57%) (BCL, 2012). Copper extraction accounts for 92% of the mining GDP, and is one of the pillars of the Chilean economy; it attracts significant foreign private investment, since its production is well developed and oriented to exports.

There are four major energy demand sectors in Chile: industry, mining, transportation, and ‘other’ (residential, commercial and public) (APEC, 2009). The industry and mining sectors together used 37% of the 2009 final energy demand; this was driven by two subsectors in particular: copper, and pulp and paper. The major energy sources consumed in these sectors are petroleum products, biomass, and electricity.

The transport sector is also a major energy user, consuming 31% of the final demand. Chile’s particular geography, high urbanization and low population density (in most centres other than greater Santiago) create the conditions for frequent long journeys. Road transportation is the predominant mode, accounting for 80% of the transport energy demand. Maritime and air transport together make up most of the remaining energy use, while the rail share of the transport energy demand is minimal, representing less than 1%.

In the medium and long term, vehicle sales growth is expected to be sustained by rising incomes and low prices. Light vehicle ownership will increase substantially from around 1.8 million cars in 2009 to 6.6 million cars in 2035. Most of the cars sold in Chile are made in Asia or elsewhere in South America by American and European automakers. There is no longer any automotive production in Chile—the last remaining local assembly plant in Chile, a General Motors plant in Arica that assembled pick-up trucks, closed in mid-2008.

Historically the railways have been important in Chile, but they now play a relatively small part in the economy’s transport system. Rail’s declining importance, including for freight transportation, is expected to continue through the outlook period.

Chile employs a concessions or public–private joint investment system to finance the construction, development and improvement of transport infrastructure such as highways, airports and urban transportation systems. The system is administered by the Ministry of Public Works (MOP). Between 1993 and 2008, USD 11.5 billion was invested in new, upgraded highways (such as Highways 5, 68, 78 and 57) as well as road maintenance and improvement of urban transportation, especially in Santiago (such as the Metro de Santiago bus system). By 2009, Chile had a total 81 000 km of roads, of which 21% was paved (MOP, 2009).

The ‘other’ sector, which covers the residential, commercial and public sub-sectors, consumed 28% of Chile’s final energy demand in 2009; 79% of this use was in the residential sector. New renewable energy (NRE) accounts for 46% of total final energy

consumption in the residential sub-sector—mostly of biomass for heating and cooking (APEREC, 2009).

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Chile has limited domestic fossil energy resources. It is largely dependent on international energy markets, which means the economy is exposed to considerable risk in terms of security of supply and price fluctuations. The economy does produce some conventional energy resources, including crude oil, natural gas, coal, and renewable energy sources such as hydro, wind and biomass. Chile is considered to have three major domestic energy resources: wood/biomass for heating and electricity generation; water for hydroelectricity generation; and natural gas from the Magallanes region.

Chile’s estimated proven crude oil reserve in January 2009 was 150 million barrels (equivalent to about 20 Mtoe) located mostly in the southern Magallanes region (Oil & Gas Journal, 2011). In 2009, production was 0.72 Mtoe (about 14 000 barrels/day), including gas liquids. By comparison, Chile’s 2009 total primary oil supply was 15.6 Mtoe. Limited local production means dependency on imports is substantial and growing. The government-owned Empresa Nacional del Petróleo (ENAP) and privately owned GEOPark are the major oil producers and refiners in the economy. ENAP operates all three refineries in Chile, the largest of which is the 113 400 barrels/day Bio-Bio refinery, located south of the capital Santiago (ENAP, 2009).

Chile’s natural gas production comes from onshore and offshore facilities in the Magallanes region. Proved reserves of natural gas were 98 billion cubic metres (or about 88 Mtoe) in 2011 (USEIA, 2011). However, Chile had limited gas production of about 1.5 Mtoe in 2009 (IEA, 2011). The economy is a net importer of natural gas, with imports accounting for 44% of the economy’s total natural gas supply in 2009. There are indications Chile may have significant resources of shale gas (see Volume 1, Table 12.2), but utilization of this resource is not included in APEREC’s business-as-usual (BAU) projection because the initial studies on shale gas in the Magallanes region only began in 2009 and information is still incomplete.

Historically, Chile’s main source of imported gas was Argentina, but Chile has faced restrictions on imports imposed by that economy since 2004 (see the ‘Energy Policies’ section below). Given the limited domestic gas production, Chile is pursuing other

sources of imports in the form of liquefied natural gas (LNG). Two major LNG import facilities commenced full-scale operation in 2011. The first, located in Quintero Bay, has a total installed capacity of 5 million cubic metres per day. The second facility in Mejillones, in northern Chile, has an installed capacity of 2.5 million cubic metres per day. Both these terminals will be expanded in the future.

Natural gas distribution is carried out by eight companies: Metrogas, Gasvalpo, Innergy, GasSur, Intergas, Gasco Magallanes, Distrinor, and Lipigas. The biggest, Metrogas, supplies industrial and residential customers in Santiago. In Valparaíso City distribution is by Gasvalpo. In the south, Innergy handles industrial distribution while residential distribution is the responsibility of GasSur and Intergas. In the far south, industrial and residential distribution is by Gasco Magallanes. In the north, Distrinor supplies Antofagasta city and Lipigas distributes within Calama city.

Chile's recoverable coal reserves were estimated at 700 million tonnes in 2008 (CNE, 2008a), or 136 years of coal supply at 2005 demand levels. Domestic coal production is in two regions: Bio-Bio in Golfo de Arauco, and Pecket and Isla Riesco in Magallanes. Production of coal is expected to reach 5–6 million tonnes.

In terms of electricity generation potential, Chile is rich in hydropower energy sources. Chile's total electricity generation in 2009 was 60.7 TWh, with 51% of this coming from thermal power plants run on coal (25%), oil (20%) or gas (6%). The rest was almost all hydro (IEA, 2011). Public utilities accounted for 91% of total electricity generation, while the remainder was generated by independent producers.

Chile's electricity grid is made up of two main systems. The Central Interconnection System (SIC) supplies 90% of the population while the Northern Interconnection System (SING) provides electricity to northern regional consumers including the mining companies located there. The two grids are not connected. In addition, there are two smaller systems serving a very small proportion of the population; these are the Aysen Interconnection System and the Magallanes Interconnection System.

Renewable energy (hydro, wind, biomass and biogas) contributed 76% of Chile's domestic energy production in 2009 (7339 ktoe). Biomass in the form of wood is the largest source of domestic energy production (50% of total indigenous production and 70% of energy from renewable sources) with most wood used in the residential sector. The second largest renewable energy contributor is hydro. In

2009 Chile produced 2228 ktoe (25 990 GWh) of hydropower, which was 22% of total indigenous energy production. Chile also has a modest potential supply of biogas from biomass treatment of waste products such as poultry dung and urban solid waste. Chile began some production of biogas in 2009, producing a total of 6.9 ktoe (12 million cubic metres) (MINERGIA, 2010). Biofuels are just starting to emerge in the automotive sector.

No other energy sources, such as nuclear or geothermal, are currently being employed, although the potential of geothermal and photovoltaic resources in Chile's energy mix is promising.

## ENERGY POLICIES

Chile's approach to the energy sector is based on the development of a free market economy. Since 1990, the economy has distinguished itself as a world leader in liberalizing the energy sector.

Chile's energy policy priority is to reduce the economy's dependence on energy imports and the associated exposure to supply shocks, which are heightened by the growing energy demand. A significant event in Chile's recent history, that has deeply influenced its subsequent energy policies, was the gas crisis that began in 2004. The background on the crisis is that in 1995, in an effort to diversify its energy supply, Chile signed a gas integration protocol with Argentina to set up a supply of competitively priced imported gas. The agreement led Chile's private sector to invest heavily in the economy's natural gas infrastructure. The gas share in Chile's power generation rose from 1% in 1996 to 33% in 2004. However, in 2004, Argentina began to unilaterally reduce energy exports, with severe impact on the gas trade with Chile, even cutting off gas exports completely in some periods during 2007 and 2008 (IEA, 2009).

In early 2012, the Chilean Government through its Ministry of Energy issued the National Energy Strategy 2012–2030 (ENE for its Spanish acronym). This document sets out long-term policy and objectives for the energy sector. It focuses on electricity issues, and on the supply of clean, competitively priced and reliable energy to Chile, to support the economy's development and to sustain economic growth. The ENE established six main goals (MINERGIA, 2012):

1. Economy-wide promotion of energy efficiency
2. Promotion of non-conventional renewable energy
3. Expansion of hydropower generation to reduce dependence on energy imports

4. A new institutional focus on electricity transmission
5. Modifications to the electricity market to make it more competitive
6. Development of electricity interconnections with neighbouring economies.

As the ENE was issued by the President and his Cabinet, it can be expected that most measures and targets in the strategy will be enforced, although there are certain parts of the ENE that depend on further regulation or legal modification, and so are less certain.

On the planning side, the ENE proposes the creation of power utility corridors that will be listed as facilities of ‘national interest’, improving small power producers with access to the grid, and the use of smart grid technology to promote the expansion of distributed generation.

On the operational side of the electricity sector, the ENE calls for more independence for existing independent power system operators in each of the two major electricity systems. This is to bring more even-handed treatment to all power producers. There is policy to introduce net metering into the Chilean market, so that families and small businesses have incentive to install renewable energy technologies with the possibility of being paid by the utility for surplus energy fed to the grid. In addition, the ENE proposes the development of electricity interconnections with Chile’s neighbours, particularly with Argentina, while also advancing efforts with Peru, Bolivia and Ecuador. This is with the intent of preventing supply disruption.

Chile’s oil and gas sector is centred on the National Petroleum Agency (ENAP), the government-owned company created in 1950 and unchanged by 1990s liberalization. ENAP presently controls the bulk of oil production and refining in the economy, supplying about 70% of Chile’s oil product demand through an extensive network for transportation, storage and distribution of crude oil, natural gas and refined products (ENAP, 2011). Despite Chile’s limited hydrocarbon resources, the economy has always aspired to securing energy supply and self-sufficiency. For this reason, ENAP carries out exploration and production activities overseas, including in Ecuador, Argentina and Egypt. Technically, Chile’s oil and gas industry is open to private companies, but in practice few investors participate due to the economy’s limited resources.

In the case of coal, domestic production is limited, accounting for little more than 5% of Chile’s coal demand in 2010 (MINERGIA, 2010). The Isla

Riesco project in the south of Chile is expected to significantly increase the domestic supply, with its annual output of approximately 6 million tonnes of coal. It is expected to start operation in the first half of 2013 (Mina Invierno, 2012a, 2012b).

Energy efficiency has become central to Chile’s work towards its key goal of reducing dependence on imported fossil fuels. The government’s dual approach in recent years—increasing the share of electricity produced from hydro and new renewable energy (NRE) sources while reducing demand growth through energy efficiency—has been strengthened through the ENE published in 2012.

The Energy Efficiency Agency (AChEE) is responsible for the promotion and enhancement of efficient energy use in the economy. This agency includes representatives of the Ministries of Finance and Energy and is responsible for implementing Chile’s Action Plan on Energy Efficiency 2020 (PAEE 2020), which is listed as the first goal of the ENE. The main target of PAEE 2020 is a 12% reduction in the forecast energy demand for 2020, roughly equivalent to 1122 MW of capacity.

The Chilean Government through AChEE is carrying out several major projects in these areas:

- *Transport Sector.* One program was carried out in 2011, replacing 144 buses older than 20 years with new, energy-efficient units. Other lines of action are currently in ‘pre-development’: developing efficient driving workshops; providing incentives for improving energy efficiency standards and technological upgrades in existing vehicles; fostering implementation of economy-wide energy efficiency management; and developing information mechanisms to promote purchase of energy-efficient vehicles.
- *Residential, Commercial and Public Sectors.* Action in these sectors is at the planning stage. The plans include a pilot project for water heaters replacement; specialized training in energy efficiency management; the inclusion of energy efficiency criteria for new buildings; a special program to carry out energy efficiency measures in public buildings; and an energy efficiency certification scheme for current buildings.
- *Industry and Mining Sectors.* There are three projects in planning in these energy-intensive sectors. They include implementation of energy management systems through the implementation of the international standard ISO 50.001; promotion of and training in cogeneration; and the development of an economy-wide list of top-quality energy advisors.

- *Business Development.* Four programs are underway, including energy audits and diagnosis.
- *Measurement and Verification.* AChEE's project management, training and monitoring software are included in this area.
- *Education and Training.* This covers several projects with wide application, including strengthening energy efficiency research and innovation in higher education institutions, and increasing people's awareness of energy efficiency issues.

In terms of electricity production from renewable energy, new legislation proposed in April 2008 aims to provide an incentive for increased use of new renewable energy (NRE) in the economy's electricity systems. Law 20.257 (the Law of Non-Conventional Renewable Energy) took effect in 2010 (CNE, 2008b) and establishes that any new power supply contract (new consumption or new supply to existing consumption) must include at least a percentage of self-generated or outsourced NRE. The share starts at 5% for the period 2010–14 and gradually builds up to 10% of total energy production by 2024.

Since the ENE's publication in 2012, renewable energy has become a higher priority, and it is expected that its share in the Chilean electricity matrix will rise in the short and long term. The ENE proposes various strategies in support of this, such as improving bidding mechanisms; expanding hydropower generation; developing a geo-referenced atlas to provide accurate information that can support investment; implementing financing schemes; and developing and implementing differentiated policies for individual technologies, which will address specific technical and economic issues.

In addition, from May 2012 one of the six sectoral committees of Chile's Economic Development Agency (CORFO) has been exclusively devoted to energy issues. The Renewable Energy Centre is in charge of supporting access to finance, supporting project development, strengthening networking and stimulating innovation in the NRE area (CORFO–CER, 2012).

In Chile, prices for petroleum-based fuels are set by market conditions across all stages of the value chain, including retail sales at service stations. However, specific excise taxes (IEC in Spanish) are charged on transport fuels (gasoline, diesel, LPG and CNG). Although Chile does not employ direct energy subsidies, a mechanism was introduced in February 2011 to reduce uncertainty about domestic prices for oil products. This is the government's Consumers'

Protection System for Volatility in International Oil Prices Volatility (SIPCO). Under this system, a price band is determined around the average price of a fuel over the past five months. If the price of the fuel rises or falls outside this band, the excise tax is varied to counteract the price change. Thus, significant variations in price are absorbed into the IEC excise tax system and consumer risk is minimized (CNE, 2012).

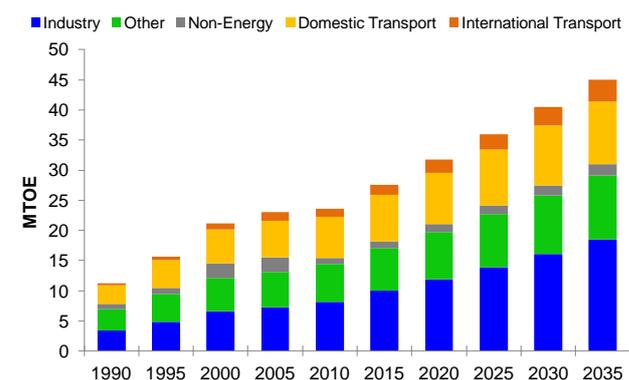
Chile is a signatory to the United Nations Framework Convention on Climate Change (1995), and ratified the Kyoto Protocol in 2002. In 2006, the government published a National Strategy on Climate Change to promote action in that area. In December 2008, to complement the strategy, Chile published the National Action Plan on Climate Change 2008–12. This action plan assigns institutional responsibilities for adapting, mitigating and strengthening Chile's response to climate change (CONAMA, 2008).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Chile's final energy demand (excluding the international transport sector) is expected to grow 88% over the outlook period, rising from 22.3 Mtoe in 2010 to 41.9 Mtoe by 2035 under business-as-usual (BAU) assumptions. By 2035 the sector with the greatest energy demand will be industry (44%), followed by 'other' (residential, commercial, and agriculture) with 26%, domestic transport with 25%, and the remaining 5% accounted by non-energy use.

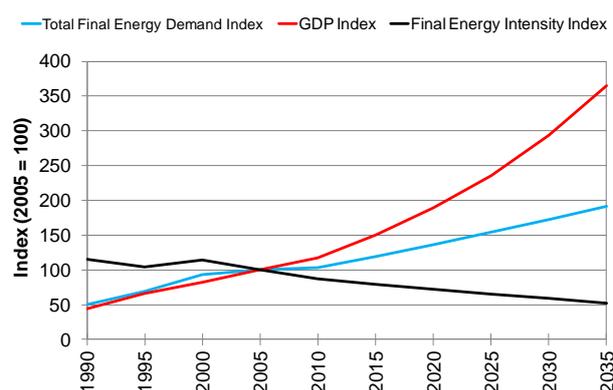
Figure CHL6: BAU Final Energy Demand



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure CHL3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the Chilean industrial sector is expected to grow almost 130% over the outlook period, rising from 8.1 Mtoe in 2010 to 18.6 Mtoe by 2035. By 2035, the largest share of this demand will be for oil products (predominantly diesel) at 44%, followed by electricity at 39%. Renewable energy sources, mostly biomass in the pulp and paper industry, are expected to be the third major energy source for the sector with 14%, while coal is bound to account for less than 1%. The use of natural gas, mainly in the mining and petrochemical industries, is expected to remain minimal, with little change from 2010 levels (about 1% in 2035). While Chile’s historically restricted gas supplies might have discouraged a more rapid expansion of natural gas in the industrial sector, this may change with the availability of more gas in the form of LNG. Our industrial gas projections could, therefore, be conservative.

### Transport

Energy demand in Chile’s domestic transport sector is expected to increase 52%, rising from 6.8 Mtoe in 2010 to 10.4 Mtoe in 2035. As with most economies, by 2035 the bulk of the sector’s energy demand is expected to be met by petroleum-based fuels (gasoline and diesel) with 94%. Biofuels, gas (CNG) and electricity (for electric cars) could account for the remaining 6% of the transport sector demand in 2035.

Chile’s light vehicle fleet is expected to double by 2035. Composition of the fleet at the end of the outlook period is expected to be mostly conventional gasoline and diesel-powered cars (81%), with conventional hybrid cars at 8%, plug-in hybrids at roughly 4%, CNG cars at 3%, and the remainder made up by LPG cars, motorcycles and and hydrogen fuel cell cars. With a current ownership level of less

than 200 vehicles per 1000 people, Chile’s vehicle ownership is far from saturation and is projected to grow steadily in line with the economy’s increasing population, urbanization rate and per capita income.

Energy use in the transport sector will grow more slowly than light vehicle ownership. This reflects slower growth in energy demand for heavy vehicles and other transport modes, along with increasingly efficient vehicles.

### Other

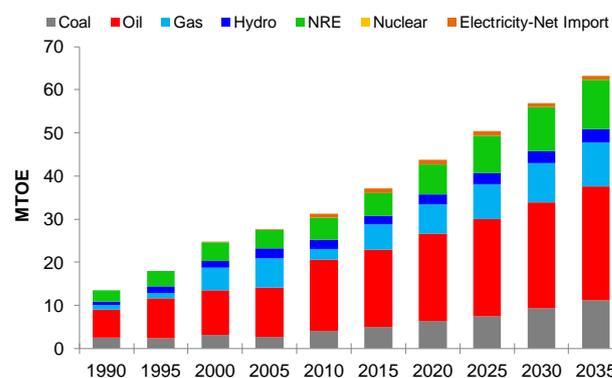
Energy demand in the residential, commercial and agriculture subsectors is expected to grow 76% in the outlook period, rising from 6.3 Mtoe in 2010 to 11.1 Mtoe by 2035. Projections indicate that all energy sources in this combined sector will experience a fairly similar growth over the period (expanding around 140% on the 2010 amount) with the exception of renewable energy, which is expected to remain flat.

### PRIMARY ENERGY SUPPLY

Chile’s primary energy supply is projected to double over the outlook period, from 31.3 Mtoe in 2010 to 63.6 Mtoe in 2035. Among the fossil fuels, natural gas will experience the largest growth, increasing four times from 2.5 Mtoe in 2010 to 10.3 Mtoe in 2035. This assumption is based on the planned expansion of the current LNG import terminals. The energy supply from petroleum products will grow 61%, rising from 16.6 Mtoe in 2010 to 26.7 Mtoe in 2035, while coal supply will grow 177% by 2035, reaching more than 11.2 Mtoe.

New renewable energy (NRE) supply is projected to more than double from 5.0 Mtoe in 2010 to 11.4 Mtoe in 2035—exceeding coal’s share to become the second largest energy source in Chile’s primary energy mix. The growth of NRE will be mainly driven by electricity generation demand growth.

Figure CHL4: BAU Primary Energy Supply

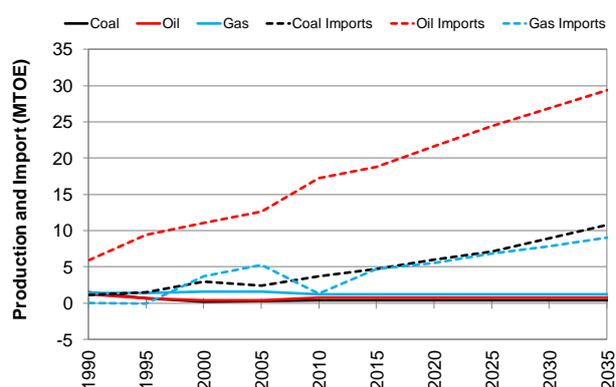


Source: APERC Analysis (2012)

Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Oil will remain dominant, accounting for 42% of Chile’s total primary energy supply in 2035, and will be predominantly used in transport and industry. Oil imports are expected to rise by about 72%, rising from 17.2 Mtoe in 2010 to 29.6 Mtoe in 2035. Without taking into account the possible impact of the Isla Riesco project on the domestic coal supply, coal imports are expected to reach 10.8 Mtoe in 2035, nearly triple its 2010 figure. Significant growth of gas imports is expected, increasing almost seven times over the outlook period from 1.3 Mtoe in 2010 to 9.1 Mtoe in 2035, as a result of the expansion of Chile’s LNG terminals.

Figure CHL5: BAU Energy Production and Net Imports

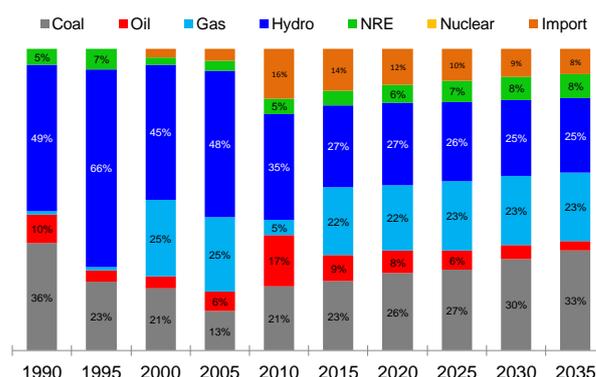


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**ELECTRICITY**

Total electricity generation in Chile is projected to grow 119% over the outlook period, increasing from 60 TWh in 2010 to 131 TWh in 2035. Coal-fired technology is expected to become a more important source, supplying 36% of the electricity generated in 2035, followed by hydro (27%) and natural gas (25%). Natural-gas-fired generation will have the largest increase, growing more than eight times in comparison to 2010 levels. At the same time, electricity generation from NRE is expected to more than triple. The increase in the use of gas for electricity generation reflects greater ability to import LNG following the expansion of the current import terminals.

Figure CHL6: BAU Electricity Generation Mix

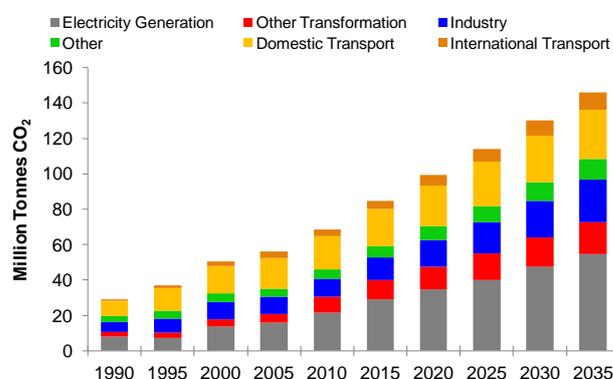


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**CO<sub>2</sub> EMISSIONS**

Chile’s total CO<sub>2</sub> emissions are projected to more than double over the outlook period, reaching 14 million tonnes of CO<sub>2</sub> in 2035 (including international transport) compared to nearly 69 million tonnes of CO<sub>2</sub> in 2010. By 2035, CO<sub>2</sub> emissions from the electricity generation sector are estimated to account for 37% of this (around 55 million tonnes), followed by domestic transport (19% or 28 million tonnes), and industry (16%, 24 million tonnes).

Figure CHL7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis reported in Table CHL1 shows GDP growth (at 4.6% per year) underlies much of the projected CO<sub>2</sub> emissions increase. The impact of this economic growth is partly offset by a reduction in the energy intensity of GDP of 1.6% per year, reflecting a shift toward less energy-intensive industry and greater energy efficiency economy-wide.

**Table CHL1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion**

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.6%	1.8%	0.5%	0.4%	0.2%
Change in Energy Intensity of GDP	-0.6%	-1.0%	-1.4%	-1.5%	-1.6%
Change in GDP	5.6%	3.3%	4.4%	4.4%	4.6%
Total Change	4.4%	4.1%	3.4%	3.2%	3.1%

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

With its efforts to promote energy efficiency and LNG imports, Chile has responded effectively to the security of supply challenges posed by the gas crisis, and has done so in an environmentally responsible fashion. Looking ahead, however, Chile's rapidly growing CO<sub>2</sub> emissions and increasing dependency on imported oil in the BAU scenario suggest additional challenges will need to be addressed in the future.

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Significant increases in Chile's domestic gas production would require Chile to have significant unconventional natural gas potential. An analysis by the United States Energy Information Administration estimated that Chile has 64 Tcf (1600 Mtoe) of technically recoverable shale gas (see Volume 1, Table 12.2). However, further investigation will be required before the economic viability of this gas can be confirmed. Therefore, the High Gas Scenario was not run for Chile and Figures CHL8–CHL10 are not included here.

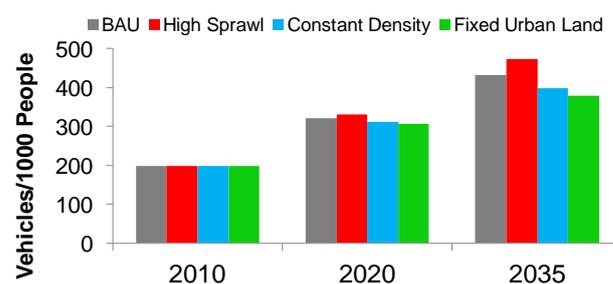
### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were created: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'.

The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CHL11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the scenarios is significant, with vehicle ownership about 10% higher in the High Sprawl scenario compared to BAU in 2035, and about 13% lower in the Fixed Urban Land scenario. This means that better urban planning will have a direct impact on vehicle ownership in the long run.

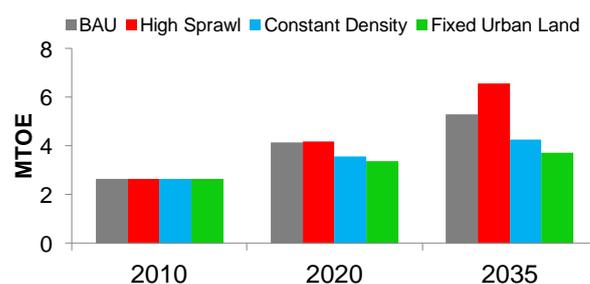
**Figure CHL11: Urban Development Scenario – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure CHL12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Light vehicle oil consumption would be 31% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 26% lower in the Fixed Urban Land scenario.

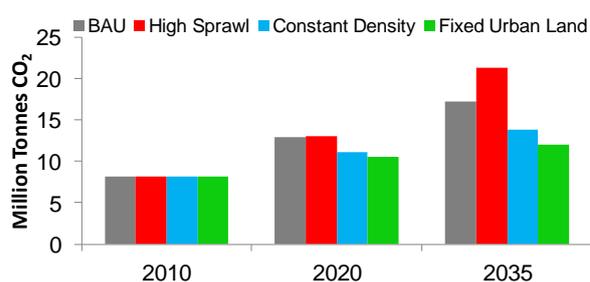
**Figure CHL12: Urban Development Scenario – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

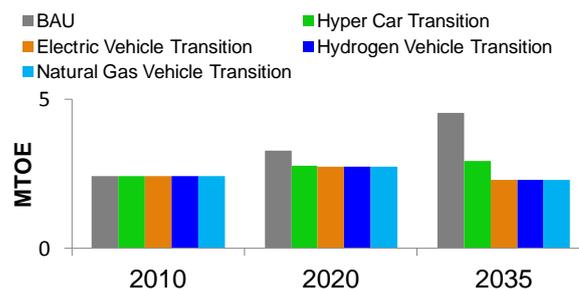
Figure CHL13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO<sub>2</sub> emissions would be 31% higher in the High Sprawl scenario compared to BAU in 2035, and about 27% lower in the Fixed Urban Land scenario.

**Figure CHL13: Urban Development Scenario – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

**Figure CHL15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



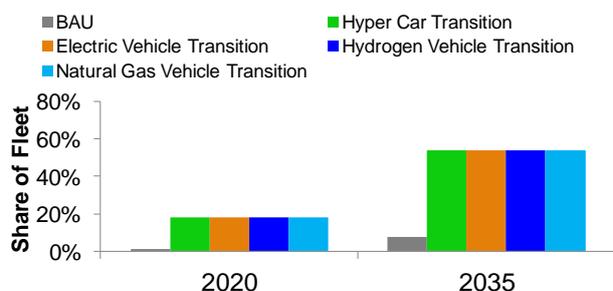
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CHL14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of alternative vehicles in the fleet reaches about 55% compared to about 8% in the BAU scenario. The share of conventional vehicles in the fleet is only about 45%, compared to about 92% in the BAU scenario.

**Figure CHL14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**

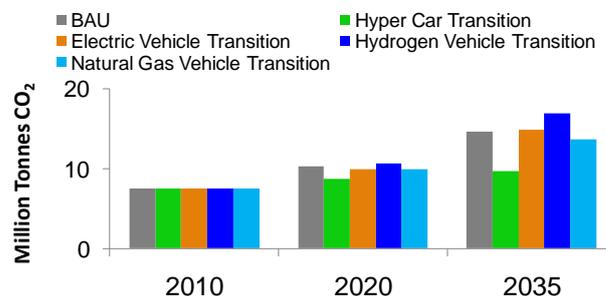


Source: APERC Analysis (2012)

Figure CHL15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by about 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to the BAU scenario by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly efficient vehicles still use oil.

Figure CHL16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure CHL16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Chile, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reduction, with emissions reduced by 34% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario offers lower emissions reduction (7% compared to BAU), reflecting the lower emissions of natural gas compared to oil. The Electric Vehicle Transition scenario offers no significant emission reduction in Chile. This is probably because coal will be the largest marginal source for electricity generation in Chile in 2035, and coal combustion produces more CO<sub>2</sub> emissions than oil or natural gas combustion. The Hydrogen Vehicle Transition scenario offers no emission benefits, in fact producing 15% more CO<sub>2</sub> compared to BAU in 2035.

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# CHINA

- Over the outlook period, rapid economic growth coupled with its efforts in energy efficiency and conservation will drive the moderate annual growth rate of 2.3% for China's final energy demand. This is compared with a GDP growth rate of 6.6% over the same period.
- The total primary energy supply is projected to grow 2.1% annually over the period. This includes average annual growth rates of 0.8% for coal, 2.7% for oil and about 7.7% for natural gas.
- The contribution of non-fossil fuels in the fuel mix for power generation will rise to 37% by 2035, up from 19% in 2009. This increase will be key to China limiting its CO<sub>2</sub> emissions over the outlook period.
- The increase in the gas share of power generation, from 1% in 2009 to 11% by 2035, also reflects China's efforts to limit its CO<sub>2</sub> emissions.

## ECONOMY

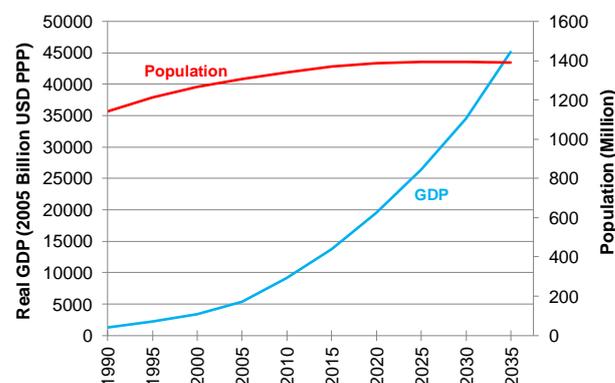
China is the fourth-largest economy in geographic size in the world, after Russia, Canada, and the United States (US). Its land area covers 9.6 million square kilometres, and features a range of landscape types, including mountains, deserts and river basins. China has by far the largest population of any economy in the world. The economy's population growth will be restrained during the outlook period, growing 0.15% per year compared with the average annual growth rate of 0.82% from 1990 to 2009. The total population is expected to increase to about 1.39 billion by 2035, an increase of about 4.3% from the 2009 figure.

China is the third-largest economy in the world after the US and Japan with a real GDP of USD 8.26 trillion (in 2005 USD PPP) in 2009. It has sustained high rates of economic growth since the early 1990s; the average annual growth rate for the period 1990–2009 was 10.5%. It is projected the high economic growth rate will slow down as China's economy matures. The projected average annual growth rate is about 6.6% during the outlook period (2010–2035). This is similar to the target set in China's 12th Five-Year Plan (2011–2015) for a GDP growth rate of 7% during those five years (APCO Worldwide, 2010).

However, China's development so far has mostly focused on its coastal area due to the access it gives to the global market and the convenience it offers to communicate with foreign economies. Another concern is that the income of many citizens has not kept pace with the fast economic growth over the past decade. To eliminate imbalances and to share the wealth around the economy, China is putting considerable effort into encouraging investment in its western area (such as land credits, lower taxes and subsidies for manufacturers, etc.) and speeding up the construction of transport systems (such as high-speed

rail, airports, highways, etc.) for both people and products. The goal is to try to balance the development around China's big territory.

Figure PRC1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Economic development has created increasing demands for air-conditioning, heating, lighting, other appliances, motorcycles, and vehicles to improve people's quality of life. This will boost the future requirements for energy infrastructure and energy consumption. The big challenge for China in the future will be to slow down the growth of energy consumption to protect the environment and to ensure the proper use of limited resources. In China's 12th Five-Year Plan for Energy Development, the projected primary energy consumption shows an annual growth rate of about 4.3% from 2011 to 2015. This represents a slowdown, compared with the 6.6% annual growth rate during the period 2005–2010 (SCC, 2013).

China is seeking to move away from its traditional role as the 'world's workshop' to being a centre of high-tech and high-value added industry. In China's 12th Five-Year Plan for National Economic and Social Development, the focus is on developing seven so-called 'strategic emerging industries' (SEIs). The aim is to increase the SEI's contribution from

approximately 5% of GDP in 2009 to 8% by 2015 and 15% by 2020 (NPC, 2011). It is hoped these industries will become the backbone of China's economy over the next decade. These seven industries are biotechnology, new energy, high-end equipment manufacturing, energy conservation and environmental protection, new-energy vehicles, new materials, and next-generation IT. Four of the industries relate to low-carbon technology for a clean environment and sustainable development. China can therefore be expected to become a leader in the low-carbon energy field.

To reduce the dependence of its economy on exports, China is expected to strongly emphasize the importance of shifting to consumption-driven growth, with domestic consumption expected to rise from 35% of GDP in 2009 to around 50–55% of GDP by 2015. Another effort will be to enhance the contribution of service industries; they are expected to account for 47% of GDP by 2015, up 4% from the 2010 level. Other policies stressed in the 12th Five-Year Plan for National Economic and Social Development include raising the minimum wage, expanding the government-funded social welfare and health care system, and reducing the gap in the quality of life between the urban and rural areas. The urban population is expected to reach 51.5% by 2015, up 4% from 2010 (NPC, 2011).

In the past, China's energy demand was driven mainly by the rapid growth of industry. In 2009, industry as a whole accounted for 48% of final energy consumption. The main area of growth was in the rise of heavy industry and energy-intensive industry after 2001. Within this sector, energy use was dominated by iron and steel (29% of all industrial energy used in 2009), followed by non-metallic minerals including the cement industry (23%). However, with the economy's efforts to re-structure the industry sector and to introduce the SEIs in the 12th Five-Year Plan, it is expected the energy intensity and carbon emission levels for the industry sector will be significantly reduced.

The domestic transport sector accounted for around 11% of final energy consumption in 2009; this increased at 7.8% annually from 2000 to 2009. This growth in demand was driven mainly by road transport, which consumed 76% of this sector's energy use in 2009. Passenger vehicle numbers, including civil and private, grew at an average annual rate of 20% from 2000 to 2009. Private vehicle ownership is expected to continue to rise rapidly in the future (NBSC, 2012). Fast growth in the truck and domestic marine fleet is also expected.

Investment in China's transport infrastructure is about CNY 6.2 trillion (USD 976 billion) for the duration of the 12th Five-Year Plan, an increase of 32% over that in the 11th Five-Year Plan. The majority of the funds will be used in highway construction. According to 12th Five-Year Plan, the scale of the economy's highway network will continue to expand. The total road mileage is expected to reach 4.5 million kilometres, and the total mileage of high-speed divided highways is expected to reach 108 000 kilometres. This highway network will connect more than 90% of the towns and cities with populations of over 200,000 people. To slow down the growth in private vehicle use, China is also making massive investments in public transport, including high-speed rail and urban mass transit rail systems. The expansion of the domestic airport and flight fleet is another way the economy is trying to balance development between its eastern and western areas.

Most of the rural areas in China now have electricity; the 2010 electrification figure was 99.4% of households (CEPP, 2010). However, electricity blackouts are still a problem in some of the rural areas. The growth in residential energy demand is mainly due to increasing urbanization (36% in 2000, and expected to reach 71% by 2035) (UN, 2012). The increase in urbanization increases energy demand, as urban residents tend to be more dependent on electricity and commercial fuels than the rural population. The urban population is currently concentrated in the eastern areas due to more industrial development and more employment opportunities. However, it can be expected that more balanced development in the future will mean higher residential energy demand in the western and rural areas.

The 'other' sector, which is mainly residential and commercial use, accounted for 33% of the economy's final energy demand in 2009. Residential energy use dominates (73% of this sector's energy use in 2009), followed by commercial at 12% and agriculture at about 6%. However, the service industry will gradually contribute more to the overall GDP, so the commercial sector is expected to consume more energy in the future.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

China has significant energy resources, particularly coal. In 2010, China was the world's largest producer and consumer of coal, as well as its fifth-largest producer and second-largest consumer of oil (EIA, 2012; BP, 2011). Estimates put China's recoverable coal reserves at around 114.5 billion

tonnes in 2010, enough to last 35 years at 2010 production levels; and 14.8 billion barrels of proven oil reserves as of December 2010, enough to last 9.9 years at 2010 production levels (BP, 2011). China's largest and oldest oilfields are located in the northeast region of the economy. China also had 2.8 trillion cubic metres (tcm) of proven natural gas reserves as of December 2010, enough to last 29 years at 2010 production rates (EIA, 2012; BP, 2011).

Investment in the exploration of energy resources was more than USD 17 billion in 2011 alone, 7% higher than in 2010. The potential new areas for oil and gas fields are the western basin area (such as Tarim Basin, etc.) and the offshore area in Bohai Bay (northeast China) (MLR, 2012). China has estimated exploitable shale gas resources of 36.1 tcm, in theory enough to meet China's gas needs for the next two centuries (EIA, 2012). It has launched a five-year plan (2011–2015) for the development of shale gas, aiming for 6.5 billion cubic metres (bcm) of shale gas production by 2015, which is equivalent to 2–3% of projected Chinese gas production in 2015; and more than 60 bcm of shale gas production by 2020. But the geological conditions are complex and will pose great technical and investment challenges.

China's fast economic development saw the economy shift from being a net oil exporter to a net oil importer in 1993. As of 2009, estimates place China as the second-largest net importer of oil. For environmental reasons, China is trying to slow down the growth rate of coal production and to limit coal consumption in the future. In the 12th Five-Year Plan for Energy Development, China will increase the share of gas in the primary energy consumption from 4.6% in 2010 to 7.5% by 2015 (SCC, 2013).

In addition to fossil fuel, China is endowed with 400 gigawatts (GW) of economic hydropower potential, more than any other economy. There is also a potential wind-based generation of 1500 GW, including 500 GW offshore and 1000 GW shore-based (CEC, 2011).

However, coal and oil resources have been used more extensively than natural gas and hydro for power generation and industrial development and this will continue into the near future. Most of the economy's existing power generation is coal based, with coal accounting for 79% of electricity production in 2009. In the 12th Five-Year Plan, China will increase the non-fossil fuel share of power generation from 8% in 2009 to 11.4% by 2015 and to 15% by 2020.

Much of the growth in China's domestic energy demand for crude oil and gas is being met by imports. The expansion of domestic crude oil

production and refinery capacity has not been sufficient to match the rapid increase in demand for diesel and gasoline. China's increased energy imports from the global oil market have had a significant impact internationally, tightening the overall balance between demand and supply. Chinese oil companies are also trying to boost overseas investment levels to ensure stable supplies. China is also seeking to increase its gas supply via pipelines from foreign economies, such as Turkmenistan, Kazakhstan, Uzbekistan, Myanmar and Russia. Negotiations with some of these economies are still ongoing. Three liquefied natural gas (LNG) terminals will be operating by the end of 2011 and another six new LNG terminals are in the planning/construction stages (EIA, 2012).

After the enactment of the Renewable Energy Law in 2005, the installation of renewable electricity generating capacity (excluding hydro) has doubled every year, from being almost non-existent before 2005. China's total installed wind turbine capacity (with grid connection) reached 2% (or 17.6 GW) of total electricity generating capacity, with a 1% (or 27.6 TWh) share of total electricity generation in 2009. The share of biomass was 2% (or 14.1 GW) of capacity and 2% (or 64.8 TWh) of electricity generation in 2009 (IEA, 2011). In addition, China has been speeding up its installation of solar photovoltaic power generation: in early 2009, the installed capacity was 300 MW with another 500 MW under construction.

Total solar cell production in China in 2009 was 4011 MW, which accounted for 42% of the world's solar cell shipments. However, at the end of 2009, the accumulated installed capacity in China was only about 300 MW, with another 500 MW under construction. Installed capacity is expected to grow to 21 000 MW by the end of 2015 (SCC, 2013). China launched the Golden Sun program in 2010 encompassing 275 projects with a capacity of 640 MW, which is expected to rise to 1000 MW over the following three years (NEA, 2010).

## ENERGY POLICIES

In a context of rising demand and constrained supply, China has made energy security the top priority in its energy policy objectives. The economy's 12th Five-Year Plan for National Economic and Social Development (2011–2015) sets out a program for the enhancement of energy security, with a strong emphasis on clean energy and energy efficiency. By 2015, China aims to have non-fossil fuels account for 11.4% of primary energy consumption, cut energy intensity by 16%, and reduce CO<sub>2</sub> emission per unit GDP by 17% from 2010 levels. By 2020, non-fossil

energy will account for 15% of China's total primary energy consumption and CO<sub>2</sub> emission per unit GDP will be 40-45% lower than in 2005 (SCIO, 2012). A number of measures have been implemented to this end. These measures include the promotion of non-fossil fuel as an energy source as well as lower carbon energy sources (especially gas); the modernization of energy industries, with the closure of inefficient small coalmines, power plants, refineries, and iron-and-steel production plants; and the introduction of efficient technologies throughout the energy supply chain, i.e. from production and transport through to consumption.

In the 12th Five-Year Plan for Coal Industry, coal production is capped at 3.9 billion tonnes by 2015. China also introduced regulatory controls to limit environmental degradation, tax evasion, and mine accidents. It aims to reduce the number of coal enterprises from about 11 000 to 4000. Although state-owned coal mines dominate in China's coal industry, non-state-owned coal mines still play an important role. For the state-owned coal mines, ownership is divided between various central, provincial, and local government agencies. About 10 big coal companies are expected to account for nearly 60% of all China's coal production by 2015. Even though coal's share will decrease from 70% in 2010 to 65% in 2015, it will continue to be China's largest energy source and a major contributor to its environmental problems (NDRC, 2012c).

China's three major state-owned oil companies dominate the economy's oil industry, and have been aggressively expanding. China has two vertically integrated firms: the China National Petroleum Corporation (CNPC) and the China Petroleum and Chemical Corporation (Sinopec). The third player is the China National Offshore Oil Corporation (CNOOC). CNPC is the leading upstream player in China and, along with its publicly-listed arm PetroChina, accounts for roughly 60% and 80% of China's total oil and gas output, respectively. Sinopec, on the other hand, has traditionally focused on downstream activities, such as refining and distribution. These sectors have made up nearly 80% of the company's revenues since 2008 and Sinopec is gradually seeking to acquire more upstream assets.

China has been seeking to increase the security of its oil supply by encouraging Chinese companies to become involved in upstream investment activities abroad in cooperation with international or local companies, and by speeding up the build-out of its strategic petroleum reserve (SPR) (Zhang and Wu, 2010). China has traditionally protected its own oil and gas companies by not allowing foreign oil companies to operate in China. However,

international oil companies (IOCs) have been granted greater access to offshore oil prospects, mainly through production sharing agreements, and they have made some progress in the Bohai Bay area (CNPC, 2012).

China's oil product prices are regulated by the government. However, it tries to align with the international crude oil market. In December 2008, China launched a fuel tax and reforms of its product pricing mechanism. This was done to tie retail oil product prices more closely to international crude oil markets, to attract downstream investment, to ensure profit margins for refiners, and to reduce energy misallocation caused by distortions in the market pricing.

Similarly, China's natural gas prices are regulated and generally well below international market rates. China has favoured manufacturing and fertilizer gas users by the relatively lower price these sub-sectors pay. To bolster investment in the natural gas sector, particularly by foreign participants, and to make domestic gas competitive with other fuels, the National Development and Reform Commission (NDRC) proposed linking gas prices indirectly to international crude oil prices, effectively raising prices. Industry analysts claim these price modifications are necessary to develop the gas market further. In mid-2010, the NDRC raised the onshore wellhead prices by 25%, and some Chinese cities have raised end-user prices in the industrial and power sectors (EIA, 2012).

Another way China seeks to secure its energy supply is by speeding up its efforts in shale gas exploration. China will seek international cooperation in this area. It will: encourage investment in US companies to learn the technology for exploring for shale gas; provide financial policies and subsidies for shale gas exploration, including price subsidies, preferential tax treatment and land subsidies; and encourage joint-ventures between local and foreign companies to explore for shale gas (NDRC, 2012b).

The 12th Five-Year Plan for Energy Development also specifies targets for the future development of nuclear and hydropower. The power generation capacity of hydropower plants will increase 47% by 2015, based on 2009 capacity. The number of nuclear energy power plants will increase from 11 in 2009 to 25 by 2015 (SCC, 2013).

Following the 2011 Fukushima Nuclear Accident in Japan, China immediately suspended approval of all new nuclear power projects and undertook a comprehensive safety review of existing and under-construction nuclear facilities—these include nuclear power plants, research reactors and fuel-cycle

facilities. The safety inspection took over 9 months and concluded that the operating reactors conform to both China's nuclear safety laws and regulations and International Atomic Energy Agency (IAEA) standards. At the same time, several areas for improvement were identified. The Nuclear Power Safety Plan (2011–20) and the Nuclear Power Mid- and Long-Term Plan (2011–20) were developed to address these issues. With the approval of these plans in October 2012 by the State Council, China officially lifted the suspension on new nuclear power plant approvals and at the same time introduced more stringent safety standards and regulations (NDRC, 2012). For example, until 2015, China will reconsider the relocation of nuclear power plant projects proposed for inland provinces to coastal provinces and will re-evaluate the proposed sites in areas that have experienced or are prone to earthquakes (Zeng Ming, et al., 2012). The legal system related to nuclear power will be improved to optimize the nuclear safety management, supervision and inspection systems. An emergency mechanism for nuclear accidents has also been established to enhance the economy's emergency response capability (SCIO, 2012).

China's electricity generation sector is dominated by five major state-owned holding companies. They generate about half of China's electricity. Much of the remainder is generated by independent power producers (IPPs), often in partnership with the privately-listed arms of the state-owned companies. Deregulation and other reforms have opened the electricity sector to foreign investment, although this has so far been limited.

In 2002, the State Electricity Regulatory Commission (SERC) was established, which is responsible for the overall regulation of the electricity sector and for improving investment and competition to alleviate power shortages. However, the wholesale and retail electricity prices are determined and capped by the NDRC. The NDRC used to be responsible for determining the annual plan price at which coal companies are obligated to sell large quantities of coal to power producers, but this annual plan price was abolished according to a recent policy issued by the State Council in 2012 (SCC, 2012a). Typically, generators negotiate directly with coal companies for long-term contracts. The NDRC has made small changes to its pricing system and, in 2009, it allowed electricity producers and wholesale end-users such as industrial consumers to negotiate with each other directly. The latest power tariff changes were from June 2010 when the government raised rates for energy-intensive industries by 50–100% to achieve energy efficiency goals for the year (EIA, 2012).

To strengthen coordination and decision-making in the energy sector, China established a high-level body—the National Energy Committee—to be in charge of coordinating China's energy strategy and deliberations on major issues in energy security. In March 2008, the National Energy Administration (NEA) was formed, under the NDRC. The NEA is responsible for developing and implementing energy industry planning, industrial policies and standards, and for administering the energy sector. This responsibility covers coal, oil, natural gas, and electric power including nuclear energy, and new and renewable sources of energy (NRDC, 2012a). In 2009, the National Energy Conservation Centre was formed within the NDRC to provide technical support for the government's energy efficiency and conservation management initiatives.

An amended version of the Renewable Energy Law was endorsed by the Standing Committee of the National People's Congress in December 2009 and came into effect on 1 April 2010. It more clearly defines the responsibilities of power grid and power generation enterprises, and it emphasizes the firm contracts for the purchase of power from renewable energy sources and the establishment of a development fund for renewable energy.

The government has established energy-efficient design standards for both residential buildings and public buildings, and a code for acceptance inspections of energy-efficient building construction. Since 2007, China has issued 46 economy-wide minimum energy performance standards (MEPS). The standards cover home appliances, industrial equipment, and business equipment. By the end of October 2011, China had an energy-efficiency labelling program covering 25 product classes. There is also a voluntary energy-efficiency endorsement label in China, to encourage more enterprises to reach a higher level in energy-efficiency. The government has also promoted high-efficiency illumination products and air conditioners, energy-efficient motors and other energy-efficient products through government subsidies (APEREC, 2012).

The government has established its own preferential procurement system for energy-efficient products, released a government procurement list of energy-efficient products, and ordered the mandatory procurement of nine kinds of energy-efficient products, including air conditioners, computers and illumination products. By the end of 2010, the market share of high-efficiency illumination products had reached 67%, and that of high-efficiency air conditioners, 70% (APEREC, 2012).

To promote energy conservation activities in the industry sector, the China Government encourages energy service companies (ESCOs) through financial and tax incentives. ESCOs provide a total energy-efficiency solution (finance, technology, operation, maintenance, etc.) for industrial energy users. They generally operate under energy performance contracts which compensate them with a share of the savings they produce for their customers. From 2005–2010, the number of energy service companies increased from 80 to over 800, the number of employees in this sector increased from 16 000 to 180 000, and energy service industry revenues grew from CNY 4.7 billion to CNY 84 billion (USD 740 million to USD 13.2 billion) (APEREC, 2012).

In the transport sector, China published its Development Plan for Energy Saving and New Energy Automobile Industry (2012–2020) to introduce more environment-friendly vehicles into the domestic market. The plan will focus on electrically-driven vehicles (EVs and FCVs) and plug-in hybrid vehicles (PHVs) to enhance the competitiveness of the economy's automobile industry, to increase energy efficiency and to reduce carbon emissions. The production and sales of EVs, FCVs and PHVs are expected to total 500 000 units by 2015, and more than 5 million units—with a 2 million unit production capacity—by 2020. Subsidies and tax exemptions are provided for EVs, FCVs and PHVs (SCC, 2012b). China is considering the introduction of a carbon tax in the future, which could provide another incentive. More than 2000 charging stations with 400 000 quick chargers for EVs will be provided by 2015. The economy is harmonizing charging methods to promote electrically-driven vehicles. EVs, FCVs and PHVs will be introduced gradually into the domestic market for both energy conservation and environmental protection (IEEJ, 2012).

China began regulating passenger vehicle fuel consumption in 2004 with the issuance of the National Standard GB 19578-2004 Limits of Fuel Consumption for Passenger Cars (UN, 2011). The standards are based on 16 weight classes and put a limit on fuel consumption by weight. To strengthen vehicle efficiency efforts, a fuel consumption testing and management mechanism was introduced in March 2011. Under this mechanism, China published a list of vehicle models that satisfied the fuel consumption standards in 2011 (CAA, 2011).

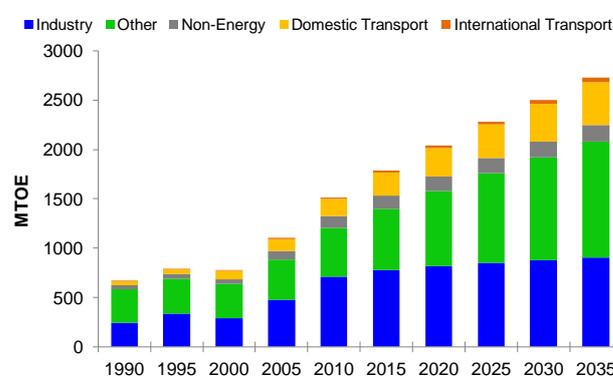
## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Over the outlook period (2010–2035), China's final energy demand is projected to grow 2.3% per year, which is a little slower than the average annual growth rate of 4.1% between 1990 and 2009.

The 'other' sector will be the biggest energy user by 2035, with a 43% share of final energy demand, followed by the industry sector (33%) and domestic transport (16%). However, the domestic transport sector has the highest average annual growth rate at 3.7%, followed by the 'other' sector at 3.5% and the industry sector at 0.9%.

Figure PRC2: BAU Final Energy Demand

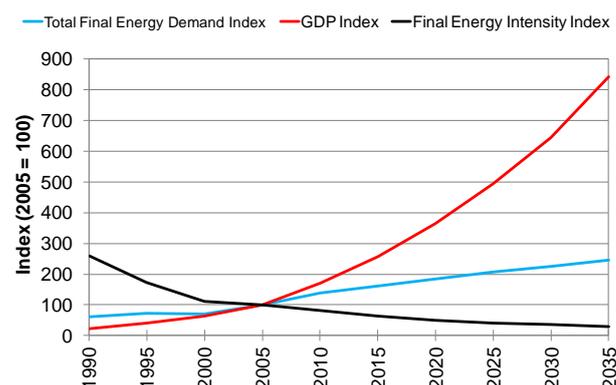


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 71% between 2005 and 2035.

Figure PRC3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

China's industry sector energy demand is projected to grow at an average annual rate of 0.9% during the outlook period. This is significantly slower than its average annual growth rate of 5.6% between 1990 and 2009.

During the outlook period, coal will still be the major source of energy in China's industry sector, although the share of other energy sources such as electricity and gas will increase. Coal's share of total industry energy demand is expected to decline to 46% by 2035, down from 59% in 2009. It is expected electricity will follow coal as the industry sector's most important energy source by 2035, accounting for 34% of China's industry energy demand. Industrial demand for gas is projected to grow very fast, at an average annual rate of 4.9% over the outlook period, but it will still account for only 6% of industry energy demand in 2035.

Within the industry sector, energy use is dominated by the iron and steel industry (25% of all industrial energy used by 2035), followed by the non-metallic minerals industry including cement (17%) and the chemical and petrochemical industry (16%). The projections also show the machinery industry will have the highest growth rate, followed by the pulp, paper and printing industry. Growth in industrial demand is limited by the overall shift from energy-intensive industries to high-value-added industries and by a bigger contribution from the service industry.

### Transport

Chinese domestic transport energy demand is expected to grow 3.7% annually over the outlook period. Domestic aviation is projected to grow the fastest with an annual growth rate of 5.8% during the outlook period, followed by domestic shipping at 4.3%, and road transport at 3.6%. Road transport will still use 75% of the transport energy in 2035, due to an increase in the number of private vehicles and the need to transport domestic goods by heavy road vehicles. Light vehicles and heavy vehicles will each use about half of the energy consumed in road transport. Projections to 2035 show the number of light vehicles will grow to about four times the number of light vehicles in 2009, at an average annual growth rate of 5.6%. Vehicle ownership in the economy will begin to approach saturation level around 2020, so the growth in ownership will slow after 2020.

China will continue its efforts to reduce energy consumption in the domestic transport sector, such as promoting clean-energy vehicles, fuel efficiency standards and fuel-efficiency labeling, mass transport systems in urban areas, and high-speed railways for inter-city transportation.

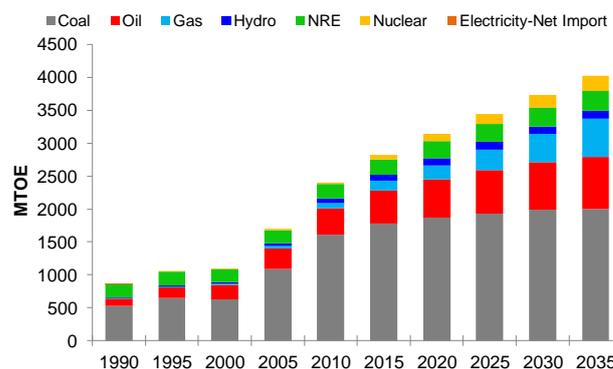
### Other

Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is primarily driven by income growth, the improvement in living standards and the expansion of the service industry. China's 'other' sector energy demand is expected to grow at an average annual rate of 3.5% over the outlook period (2010–2035). Electricity is expected to continue to dominate the energy mix, accounting for 37% of 'other' sector energy consumption by 2035, followed by new renewable energy (NRE) at 19% and natural gas at 18%. Energy-efficiency improvements in the building sector (including appliances) are a major force slowing down energy demand growth in the 'other' sector.

### PRIMARY ENERGY SUPPLY

China's total primary energy supply is projected to grow at an average annual rate of 2.1% over the outlook period. This is slower than the average annual growth rate of 5.2% from 1990–2009. This is mainly due to a projected slowdown in the GDP growth rate and efforts to improve energy efficiency.

Figure PRC4: BAU Primary Energy Supply



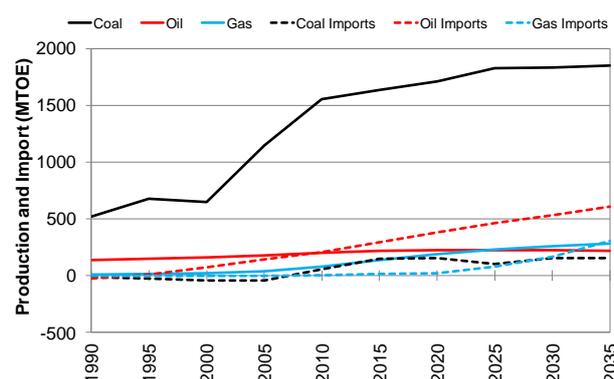
Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Among the fossil fuels, natural gas will grow the fastest (8% per year), followed by oil (2.7%) and coal (0.9%). Hydro and nuclear energy are expected to play a key role in reducing China's CO<sub>2</sub> emissions. Projected annual growth rates are 2.3% for hydro and 10% for nuclear over the outlook period, while new renewable energy has a projected annual growth rate of about 1.4%.

If the exploration for shale gas is successful and major progress is made in the future, the share of gas in the primary energy mix will grow faster than the BAU case projection.

Figure PRC5: BAU Energy Production and Net Imports

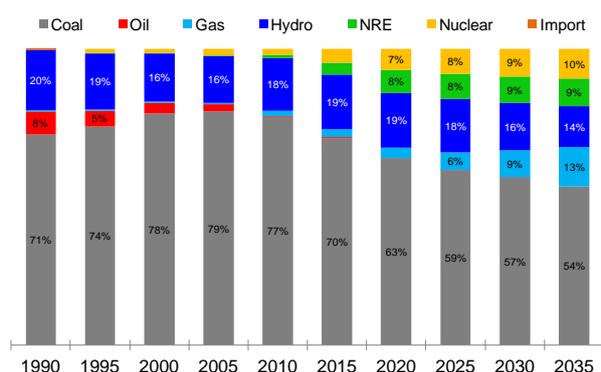


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**ELECTRICITY**

Electricity generation in China will increase by 3.3% per year over the outlook period. Non-fossil energy (such as NRE, nuclear, and hydro) will gradually increase its share in the fuel mix for power generation from 21% in 2009 to 33% by 2035.

Figure PRC6: BAU Electricity Generation Mix



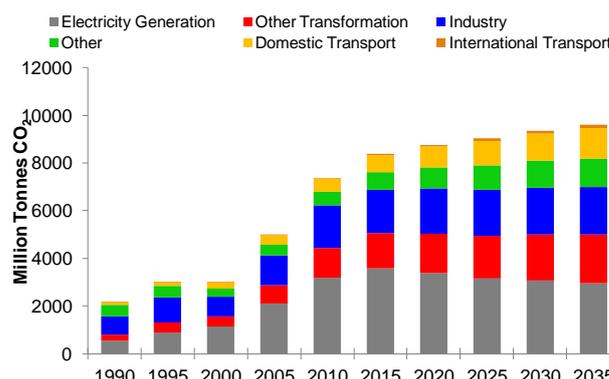
Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Throughout the outlook period, coal will maintain its dominant share in the electricity generation mix. It is projected to provide around 54% of generation by 2035, down from 77% in 2010. Generation based on natural gas will provide about 13% of the total generation mix by 2035. In coastal areas, gas-fired generation will replace coal-fired generation, as a result of reforms aimed at reducing carbon emissions and air pollution.

**CO<sub>2</sub> EMISSIONS**

Over the outlook period, China's total CO<sub>2</sub> emissions are projected to increase from 6870 million tonnes of CO<sub>2</sub> in 2009 to 11 288 million tonnes by 2035. Of the 2035 emissions, 39% will come from the electricity generation sector (about 4145 million tonnes) and 18% from industry (1994 million tonnes).

Figure PRC7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table PRC1 shows that the growth in China's GDP is largely decoupled from energy consumption and CO<sub>2</sub> emissions. Growth in GDP is largely offset by the declining energy intensity of GDP (due mainly to increasing energy efficiency and a shift away from energy-intensive industry) and the declining carbon intensity (due mainly to a declining share of coal in the energy mix).

Table PRC1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2010-2030	2030-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	1.1%	2.0%	-0.3%	-0.3%	-0.8%
Change in Energy Intensity of GDP	-5.1%	-4.8%	-4.5%	-4.5%	-4.4%
Change in GDP	10.2%	11.2%	7.7%	7.4%	6.6%
Total Change	5.7%	8.0%	2.5%	2.2%	1.1%

Source: APERC Analysis (2012)

**CHALLENGES AND IMPLICATIONS OF BAU**

China has significant energy resources, particularly coal, oil and hydro. The shale gas potential may play an important role in the future. However, the development of these energy sources is unlikely to meet the economy's growing demand for energy. In particular, net import dependency on oil is projected to increase from 57% in 2009 to 78% by 2035. The economy's growing import dependency, combined with depleting domestic resources, raise concerns about China's energy supply security. Even without significant supply shocks, such a high dependency on imported oil may impede China's economic growth due to the instability of energy prices.

China's new 12th Five-Year Plan and policy initiatives to promote energy efficiency are expected to reduce the economy's energy intensity significantly. However, China's continued economic growth, projected increases in living standards, and high reliance on coal, mean its greenhouse gas emissions are still expected to climb significantly.

Since China is likely to be the world’s largest energy consumer in 2035, it will need to be a key player in worldwide efforts to reduce greenhouse gas emissions.

### ALTERNATIVE SCENARIOS

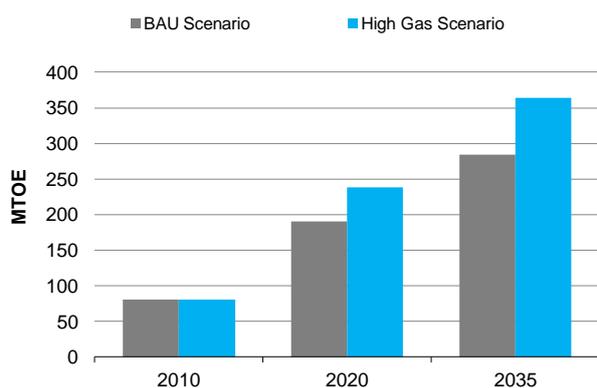
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The extra gas production for China in the High Gas Scenario comes mainly from the economy’s development of its shale gas resources. China is one of the APEC economies possessing a major resource potential for shale gas. However, the development of shale gas in China will pose major technical and policy challenges. In this High Gas Scenario, we assumed China can overcome these challenges. Figure PRC8 shows an increase in gas production of 28% by 2035, compared with the BAU case.

Figure PRC8: High Gas Scenario – Gas Production



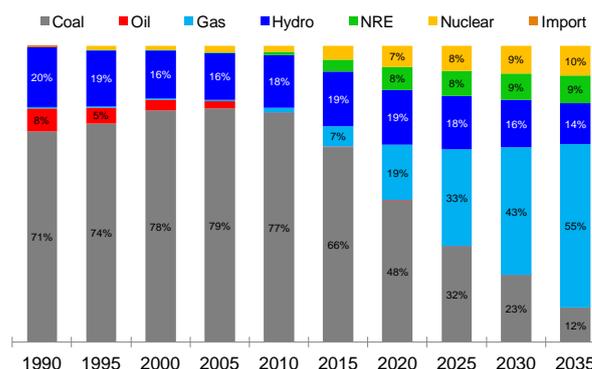
Source: APERC Analysis (2012)

Additional gas consumption in China in the High Gas Scenario will depend on the extra production of shale gas, as well as the LNG and pipeline natural gas imported from other economies. We also assumed all the additional gas would be used to replace coal in electricity generation. The electricity sector relied heavily on coal-fired power plants in the BAU case,

so the sector has plenty of opportunity to replace coal by gas.

Figure PRC9 shows the fuel mix for power generation in this High Gas Scenario. This figure may be compared to Figure PRC6 above. The projection shows the share of gas in electricity generation in 2035 has increased by 42%, from 13% in BAU to 55% in the High Gas Scenario. At the same time, coal share has declined by the same amount to 12%.

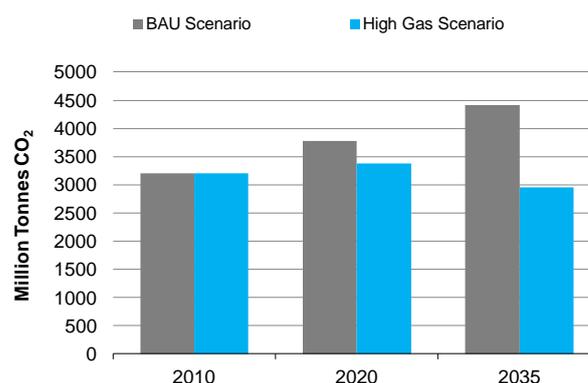
Figure PRC9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by 33% in 2035. Figure PRC10 shows this CO<sub>2</sub> emissions reduction.

Figure PRC10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation



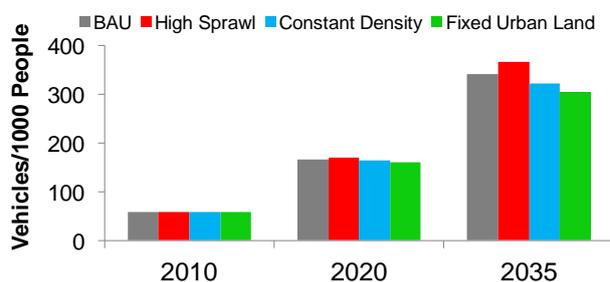
Source: APERC Analysis (2012)

## ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PRC11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the cases is significant. By 2035, vehicle ownership would be about 7% higher in the High Sprawl scenario, compared with the BAU scenario, and about 6% and 11% lower in the Constant Density and Fixed Urban Land scenarios respectively. Given that China is still under a period of fast development, vehicle ownership has a lot of room to increase. This is especially true if sprawling development patterns make it difficult for people to live without a car. The model results suggest that better urban planning could significantly reduce the need for people to own vehicles.

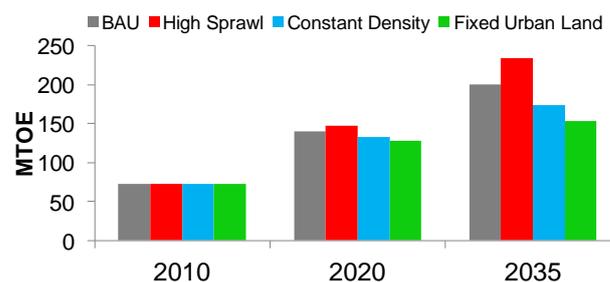
*Figure PRC11: Urban Development Scenarios – Vehicle Ownership*



Source: APERC Analysis (2012)

Figure PRC12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is even more pronounced than on vehicle ownership—more compact cities reduce both the need for vehicles and the distances they must travel. In 2035, light vehicle oil consumption would be 17% higher in the High Sprawl scenario, compared with the BAU scenario, and about 13% and 24% lower in the Constant Density and Fixed Urban Land scenarios respectively.

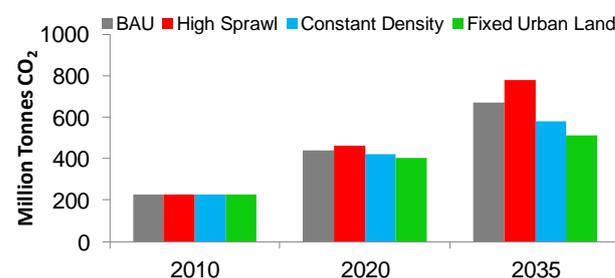
*Figure PRC12: Urban Development Scenarios – Light Vehicle Oil Consumption*



Source: APERC Analysis (2012)

Figure PRC13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases. In 2035, light vehicle CO<sub>2</sub> emissions would be 17% higher in the High Sprawl scenario, compared with the BAU scenario, and about 13% and 24% lower in the Constant Density and Fixed Urban Land scenarios respectively.

*Figure PRC13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions*



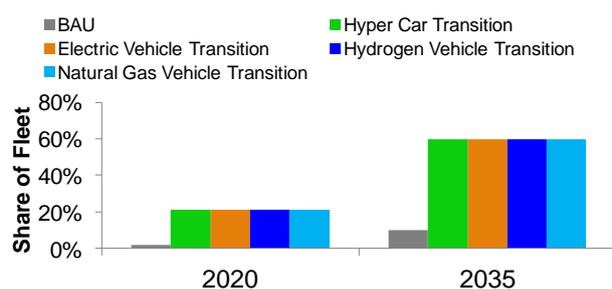
Source: APERC Analysis (2012)

## VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PRC14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 90% in the BAU scenario.

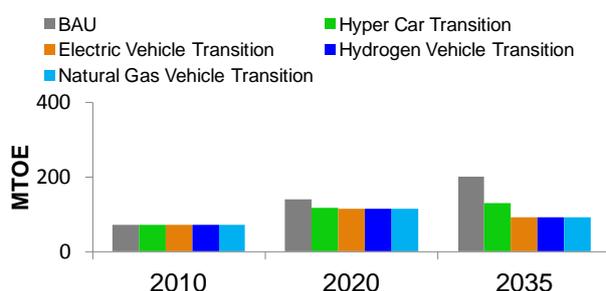
**Figure PRC14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure PRC15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 54% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 36% by 2035—even though these highly-efficient vehicles still use oil.

**Figure PRC15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

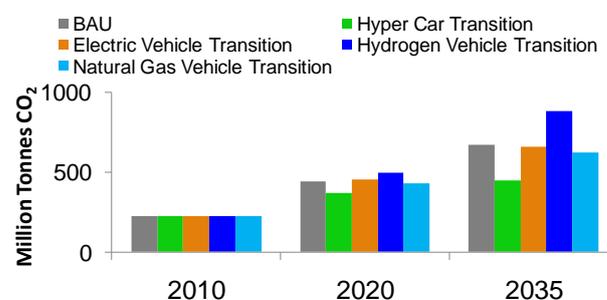
Figure PRC16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In China, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reductions, with an emissions reduction of 33% compared with BAU in 2035. The Electric Vehicle Transition scenario offers an emissions reduction of about 2% and the Natural Gas Vehicle Transition

scenario a reduction of about 7% compared with BAU in 2035. The limited reduction in the Electric Vehicle Transition scenario is principally because the marginal source for the added electricity demand is mainly coal, which is more carbon-intensive than oil. However, if introduction of electric vehicles were combined with a re-structuring of the fuel mix for the power sector, China could achieve a bigger emissions reduction.

The result for the Hydrogen Vehicle Transition scenario shows an increase of CO<sub>2</sub> emissions of 31% by 2035. This is mainly due to the way hydrogen is produced—from steam methane reforming of gas, a process which involves significant CO<sub>2</sub> emissions. However, the results would be more favourable if the hydrogen could be produced from a renewable or low-carbon energy source.

**Figure PRC16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# HONG KONG, CHINA

- *Hong Kong, China's primary energy supply is projected to grow at an average annual rate of 1.3% over the outlook period. Most of the increase is due to the demand for gas for power generation; however, coal will still be the major primary energy supply fuel in 2035 with almost 40% share of the total primary energy supply, followed by gas with a 35% share.*
- *Hong Kong, China is expected to be increasingly dependent on imported energy from mainland China, with import levels almost doubling between 2010 and 2035.*
- *CO<sub>2</sub> emissions are projected to increase mainly due to oil consumption which accounts for 65% of total emissions. International transport will account for over half of total emissions by 2035.*

## ECONOMY

Hong Kong, China is one of the special administrative regions of the People's Republic of China. It borders Guangdong to the north and is surrounded by the South China Sea to the east, west and south. Hong Kong, China is an international financial centre, and has a highly developed free market economy.

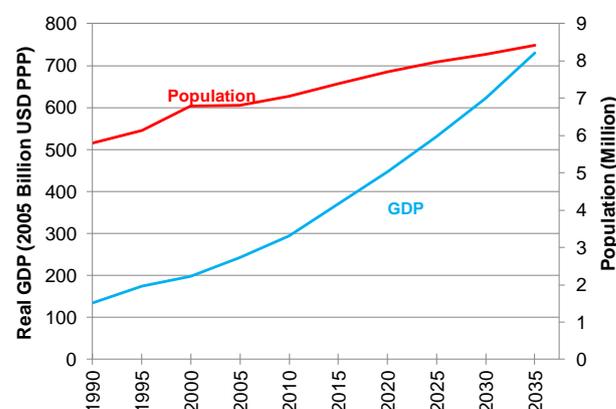
Hong Kong, China has been transforming itself into an almost entirely services-based economy. Its GDP is expected to grow at an average annual rate of 3.7% over the outlook period (2010–2035); this is similar to the average annual growth of 3.8% between 1990 and 2009. Besides the economy's traditional strengths in the financial, logistics, property, tourism and services industries, Hong Kong, China's projected growth is based on an increase in knowledge-based and services industries (CSD, 2012).

Hong Kong, China has identified four key industries within the service sector; they are financial services, trading and logistics, tourism, and producer and professional services. These four industries contributed 58% of GDP (average annual growth rate was 5.5% from 2005–2010) and employed 48.2% of the total persons employed in 2010. Another six industries in the service sector are also identified as high potential development industries by the Hong Kong, China Government. These are cultural and creative industries, medical services, education services, innovation and technology, testing and certification services, and environmental industries. These six industries contributed 8.4% of GDP (average annual growth rate was 3.4% from 2008–2010) and employed 11.6% of the total persons employed in 2010. By 2035, it is expected that the services sector will contribute more than 95% of GDP, compared with 92.9% in 2010.

Hong Kong, China's population is expected to grow slowly at an average annual rate of 0.7% over the outlook period, reaching 8.4 million people in

2035. Among the APEC economies, Hong Kong, China ranks highly for GDP per capita and has a higher standard of living than many of the other economies. The economy has a high population density. Its high urban intensity and high-rise buildings have made it appropriate to use advanced energy efficiency technology to reduce energy consumption in the commercial and residential sectors. However, it has also had a negative impact on the quality of the living environment, creating too much congestion and too little green space in the built up areas. A key issue for the Hong Kong, China Government will be to maintain a balanced '3-E' (economy, energy, and environment) development policy in the future.

Figure HKC1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Hong Kong, China's economy has a firm foundation in its strong financial services sector. It is expected to continue to shift towards higher-value-added services and a knowledge-based economy. To stay competitive and to attain sustainable growth, Hong Kong, China is attempting to restructure and reposition itself to face the challenges posed by globalization and closer integration with mainland China. The Mainland and Hong Kong Closer Economic Partnership Arrangement (CEPA) is an example of the opportunities the economy has under the 'One Country, Two Systems' relationship with

mainland China. The liberalization of trade in goods under CEPA means all products of Hong Kong, China origin enjoy tariff-free access to mainland China—on application by local manufacturers, and if the CEPA rules of origin are satisfied.

The government's strategy is to move economic activity up the value chain by: speeding up structural transformation to a high-value, knowledge-based, and skill-intensive economy; pursuing reforms in education and population policy to achieve the talent pool required; and leveraging on the immense business opportunities available in mainland China. There are four economic sectors where Hong Kong, China has a competitive advantage over mainland China: trade and logistics, tourism, financial services, and professional services and other producer services.

In Hong Kong, China, the public transport systems (including rail, bus and ferry) are estimated to carry more than 90% of all person trips in 2008 (Transport Department, 2012b). The number of observed public transport boardings is about 11.65 million a day (Transport Department, 2012a). While road transport is highly visible in the city, the rail system plays a significant role in the transport sector, with more than 246 kilometres of routes and a carrying average of about 4.5 million passengers every day in 2010. Its ridership has increased at about 3% annually from 2001 to 2010, higher than the average annual growth rate of private vehicles at 2.2% (Transport Department, 2012a). The total franchised bus system has more than 578 lines with a daily ridership of about 2.3 million (Transport Department, 2012a). There are also about 7000 non-franchised buses providing transport services. This shows mass transportation is increasing in importance in Hong Kong, China.

As a regional aviation hub, as well as being the gateway to the Pearl River Delta (PRD) area of mainland China, Hong Kong, China's international airport has a significant throughput, serving more than 100 airlines and 53.9 million passengers in 2011 (Hong Kong International Airport, 2012). Hong Kong, China's energy use for international aviation is significant—petroleum products for international aviation accounted for about 89% of energy use in the whole transport sector in 2009. In the future, mainland China's increasing participation in global economic activities is expected to speed up the growth of passenger air travel between Hong Kong, China and mainland China.

The globalization of economic activities has also increased the freight volume of air and shipping transport. Hong Kong, China can handle more than

400 cargo ships a week from more than 80 international companies. The maximum handling capacity for containers is more than 2.3 million sets a year, being mainly import/export cargos for southern China. It is expected that international transport will account for the about 94.3% of the energy used in the transport sector in 2035.

Concerning final energy consumption (excluding international transport) in Hong Kong, China in 2009, the commercial sector used the most energy at 58%, followed by the residential sector at 25%. Due to its tropical climate, air conditioning is a significant part of residential energy use, accounting for about 20% of residential demand in 2009. The relatively slow growth of energy consumption by air conditioning in residential energy use (the overall growth from 1999–2009 was only 16.5%) appears to reflect market saturation for air conditioning units/systems. Similarly, there was almost no growth in air conditioning use in the commercial sector over the period 1999–2009 (EMSD, 2012).

## **ENERGY RESOURCES AND INFRASTRUCTURE**

The absence of a domestic energy source has made Hong Kong, China a net importer of oil products (mostly from Singapore, which supplies about 80% of its motor gasoline requirements). The economy also imports natural gas—100% of this came from mainland China in 2010. Privately-owned electric and gas utilities service the economy's daily requirements.

Towngas and liquefied petroleum gas (LPG) are the two main types of fuel gas used throughout Hong Kong, China. Towngas is distributed by the Hong Kong and China Gas Company Limited. It is manufactured at plants in Tai Po and Ma Tau Kok, using both naphtha and natural gas (from October 2006) as the feedstock. LPG is supplied by oil companies and imported into Hong Kong, China through the five terminals on Tsing Yi Island.

In 2010, the total installed electricity generating capacity serving Hong Kong, China was 12 644 MW, including capacity in Guangdong, mainland China contracted to utilities in Hong Kong, China. All locally generated power is thermal fired. Electricity is supplied by CLP Holdings Limited (CLP) and Power Assets Holdings Limited (PAH). CLP supplies electricity from its Black Point (2500 MW), Castle Peak (4108 MW) and Penny's Bay (300 MW) power stations (CLP, 2012). Natural gas is the main fuel at Black Point, and coal the main fuel at Castle Peak. The natural gas is imported from the Yacheng 13-1 gas field off Hainan Island in southern China, via a

780 kilometre high-pressure submarine pipeline. CLP is contracted to purchase about 70% of the power generated at the two 984 MW pressurized-water reactors at the Guangdong Daya Bay Nuclear Power Station, to help meet the long-term demand for electricity in its supply area. It also has the right to use 50% of the 1200 MW capacity of Phase 1 of the Guangzhou pumped storage power station at Conghua, in mainland China.

Electricity for PAH is supplied from the coal and gas fired Lamma Power Station, which has a total installed capacity of 3736 MW (PAH, 2012). Natural gas used at this station is mainly imported through a submarine pipeline from the Dapeng LNG terminal in Guangdong.

## ENERGY POLICIES

In its latest 2011–2012 policy address, the government of the Hong Kong Special Administrative Region (SAR) announced it will pursue two key energy policy objectives (Office of the Chief Executive, 2012). The first is to ensure the energy needs of the community are met safely, efficiently, and at reasonable prices. The second is to minimize the environmental impact of energy production and consumption, and to promote the efficient use and conservation of energy.

In keeping with the free market economic policy of Hong Kong, China, the government intervenes only when necessary to safeguard the interests of consumers, to ensure public safety, and to protect the environment. The government works with the power, oil and gas companies to maintain strategic reserves of coal, diesel, gas and naphtha. It monitors the performance of the power companies and other energy providers through the Scheme of Control Agreements, most recently revised in 2008, to encourage energy efficiency, quality services, and the use of renewable energy (Environment Bureau, 2012).

Hong Kong, China proposes to optimize its fuel mix to promote power generation with low carbon emissions. This will mean significantly reducing its reliance on fossil fuels, phasing out existing coal-fired generation units, and increasing the use of non-fossil, cleaner and low-carbon fuels, including renewable energy and imported nuclear energy. Its plan is that, by 2020, natural gas will account for about 40% of its fuel mix for power generation, coal no more than 10%, renewable energy about 3%–4%, and imported nuclear generated energy the remaining 50% (EPD, 2012). However, it faces a challenge from environmental groups, especially after the Fukushima nuclear disaster in Japan in March 2011. The role of

clean energy in the future generation mix will be carefully re-evaluated to address their concerns.

Hong Kong, China will also endeavour to enhance energy efficiency, promote green buildings, encourage electricity savings, facilitate low-carbon transport and develop facilities to turn waste into energy. By implementing this strategy, the economy expects to: reduce energy intensity by 45% by 2035 and carbon intensity by 50%–60% by 2020 from 2005 levels; decrease its greenhouse gas (GHG) emissions by 19%–33% by 2020 compared with 2005; and lower its greenhouse gas emissions per capita from 6.2 tonnes in 2005 to 3.6–4.5 tonnes in 2020.

To help monitor the energy situation, Hong Kong, China has developed an energy end-use database. The database provides a useful insight into the energy supply and demand situation, including energy consumption patterns and trends, and the energy use characteristics of individual sectors and subsectors. A basic data set is publicly available on the internet. The government can use this data to analyse the current situation and to generate valuable policy/strategy revisions to implement in the future. The private sector can use the data to benchmark their energy efficiency so they can make further improvements in their energy consumption systems (EMSD, 2012).

A memorandum of understanding (MOU) signed by the Hong Kong, China Government and the National Energy Bureau of the People's Republic of China on 28 August 2008 ensures the long-term and stable supply of nuclear generated electricity, and the supply of natural gas from three different sources: offshore gas, piped gas and LNG (liquefied natural gas) from an LNG terminal built as a joint venture on a neighbouring mainland China site. Gas-fired power plants generated 28.8% of the economy's electricity in 2009. To improve air quality and to address the challenges posed by global warming, the government is exploring ways to gradually increase the use of clean energy. The inter-governmental MOU contemplates the delivery of gas for electricity generation in Hong Kong, China from three sources:

- (a) New gas fields to be developed in the South China Sea.
- (b) A second West-to-East gas pipeline, bringing gas from Turkmenistan through China.
- (c) An LNG terminal located in Shenzhen, mainland China.

In 2009, the Hong Kong, China Government approved the extension of the contracts for CLP to purchase nuclear generated power from Guangdong

Daya Bay Nuclear Power Station from 7 May 2014 to 6 May 2034. These contracts will enable the continued supply of non-carbon emitting electricity to Hong Kong, China for another 20 years.

In Hong Kong, China, franchised buses are the major cause of roadside air pollution in busy corridors. The government's policy objective is to have zero-emission buses running across the territory in the long term. When the current bus franchises expire in the next few years, Hong Kong, China will impose additional requirements on the franchises. The bus companies will be required to switch to zero-emission buses or the most environmentally-friendly buses available when replacing existing ones, taking into account the feasibility and affordability for bus operators and passengers.

In terms of fuel consumption and other measures of environmental performance, hybrid buses are currently superior to ordinary diesel buses. In view of market availability and technical developments, hybrid buses have the potential to replace diesel buses on a large scale in the near future, before electric or fuel cell buses become available to the market. To reach its long-term goal for zero-emission buses, the government will provide financial support to bus companies that wish to test zero-emission buses, such as electric buses.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

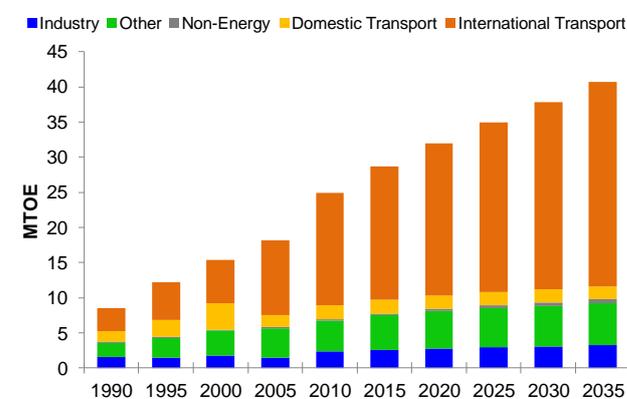
In this business-as-usual (BAU) case, the new fuel mix for power generation proposed by the Hong Kong, China Government was not taken into account in our BAU simulation for the electricity supply system. This was due to the policy still being under debate, with no final decision reached at the time of this writing. The final results of our simulation may differ from those the government proposes. However, our BAU simulation does reflect the current energy policy of Hong Kong, China.

In the simulation, the final energy demand is expected to grow at only 1% a year over the outlook period (2010–2035). If the international transport sector is discounted, the 'other' sector (residential, commercial and agriculture) will account for the largest share of energy consumption at 6 Mtoe in 2035, followed by the industry sector at 3 Mtoe. However, the projection also shows international transport energy consumption has the potential to increase to about 29 Mtoe in 2035, compared with 15 Mtoe in 2009.

By implementing different measures for energy conservation in the building sector (including for

appliances) and by continuing service-oriented GDP growth, the economy's final energy intensity is expected to decline by about 49% between 2005 and 2035.

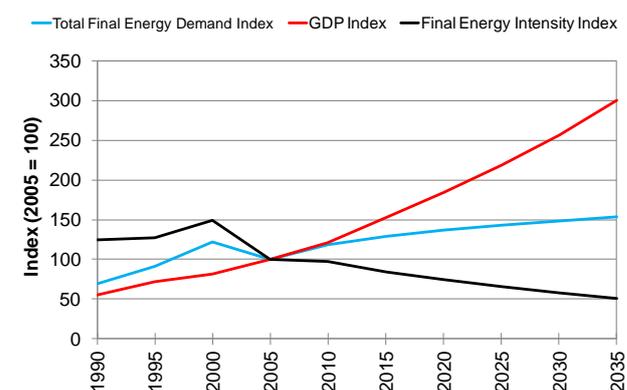
Figure HKC2: BAU Final Energy Demand



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure HKC3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 1.3% over the outlook period. This is lower than the average annual growth rate of 2.1% between 1990 and 2009. The slowdown in the energy demand growth rate is due to the slow growth in the value of industrial production expected in the future, and to the relocation of many industries, especially the energy-intensive and labour-intensive ones, to mainland China.

### Transport

Transport sector energy demand (including international and domestic demand) is projected to increase by about 73% by 2035, based on the 2010 demand figures. Almost all the increase will come from the energy demand for international transport. Domestic demand is projected to decrease by 12.2%

in the same period. The dramatic increase of energy demand for international transport is due to Hong Kong, China’s location at the gateway to the Pearl River Delta (PRD) area of mainland China and to its position as a regional aviation hub. The projection also shows international aviation demand grows by about 57% from 2010 to 2035. Marine demand grows even faster, at 95% over the same period. The result reflects Hong Kong, China’s ambitions to be a regional transfer hub for both air and marine transport. The decrease in energy demand for domestic transport is probably due to a decline in vehicle numbers and the growing use of mass transport systems (both rail and bus). The policy to gradually increase the use of hybrid and electrical vehicles will also reduce energy consumption for domestic transport.

**Other**

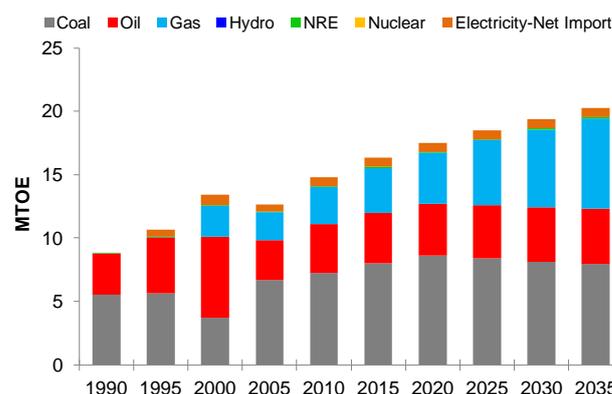
The demand for energy in Hong Kong, China’s ‘other’ sector is expected to grow at an average annual rate of 1.2% over the outlook period (2010–2035). Energy demand in the ‘other’ sector, which includes residential, commercial, agricultural and construction demand, is primarily driven by income growth. It appears most of the growth in the ‘other’ sector is commercial, reflecting the overall growth of this sector and particularly of service industries. Residential demand is growing slowly, reflecting Hong Kong, China’s focus on improving energy efficiency. Energy efficiency improvements, such as the mandatory implementation of building energy codes, the mandatory/voluntary energy efficiency labeling schemes for appliances, the adoption of high-efficient lighting fixtures/systems, and the promotion and implementation of district cooling systems for the commercial sector are the major driving forces slowing down the energy demand growth rate in the ‘other’ sector. Electricity is expected to continue to dominate the energy mix, accounting for 76% of ‘other’ sector energy consumption in 2035.

**PRIMARY ENERGY SUPPLY**

Hong Kong, China has no domestic energy reserves or petroleum refineries. The economy imports all of its primary energy needs. The total primary energy supply (excluding energy consumption for international transport) is projected to grow at an annual rate of 1.3% during the outlook period. The shift from coal to natural gas for power generation will result in a dramatic increase in the share of natural gas in the primary energy supply (excluding international transport) from 20% in 2010 to 35% by 2035. The share of coal will decrease from 49% in 2010 to 39% in 2035. During the outlook

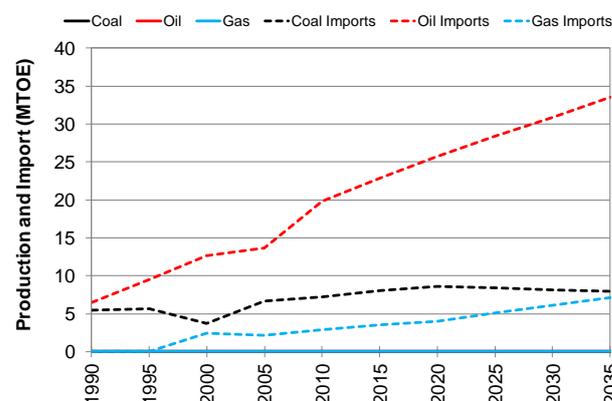
period, oil will show a minor increase, however, the share will decrease from 26% in 2010 to 22% in 2035. The results shown in Figure HKC4 do not include international transport, as fuel for international transport is not included in Primary Energy Supply. In this BAU case, the newly proposed fuel mix using an increasing amount of power imported from the nuclear energy power plant in mainland China is not included in this simulation.

*Figure HKC4: BAU Primary Energy Supply*



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

*Figure HKC5: BAU Energy Production and Net Imports*



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**ELECTRICITY**

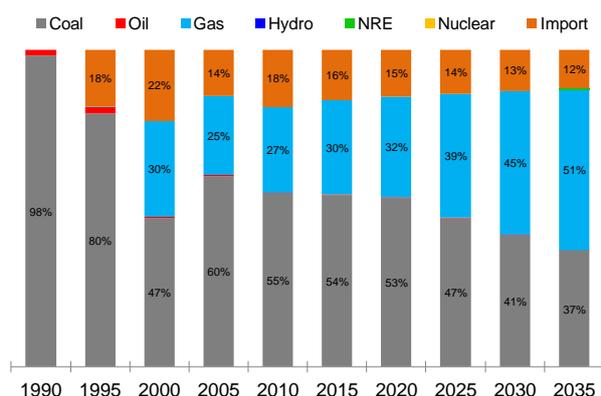
Hong Kong, China’s electricity generation output is projected to increase at an average annual rate of 1.6%, reaching 61 TWh in 2035. The economy’s commitment to reducing its GHG (greenhouse gas) emissions by 19%–33% by 2020 compared with 2005, means additions to the total installed electricity capacity are expected to be natural gas based, rather than coal fired. Coal’s share of total electricity generation is expected to fall from 55% in 2010 to 37% in 2035.

Hong Kong, China’s electricity supply is strongly dependent on power generated in mainland China.

Net imported electricity contributed to about 18% of electricity supplied in 2010. Most of the imported electricity comes from power generated at the Guangdong Daya Bay Nuclear Power Station; a small percentage comes from a storage hydropower plant in Guangzhou.

In this BAU scenario, the new proposed fuel mix for power generation is not included. The only consideration was to keep the net imported electricity amount from mainland China at the same level as in 2010, and to gradually increase the gas-fired power plants by phasing out the old coal-fired power plants. It means the increase of nuclear generated power imported from mainland China is not taken into account in this projection. Another uncertain issue in Hong Kong, China that needs to be clarified is the contribution of new renewable energy (NRE) to power generation. Considering the economy’s land limitations, our BAU projection assumes NRE will be mostly demonstration projects, and its contribution will be small.

Figure HKC6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

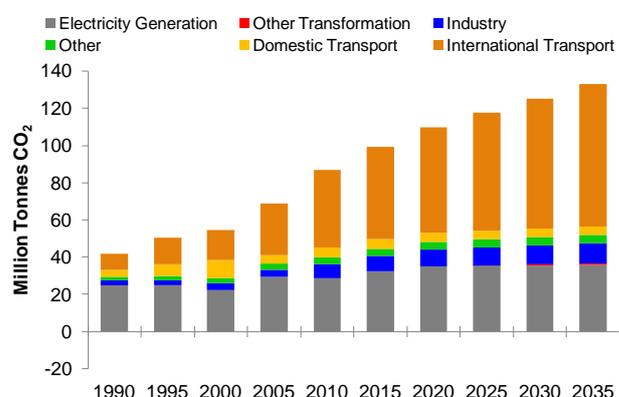
**CO<sub>2</sub> EMISSIONS**

Over the outlook period, Hong Kong, China’s total CO<sub>2</sub> emissions from fuel combustion are projected to reach 133 million tonnes of CO<sub>2</sub>, which is 53.3% higher than in 2010 and 217% higher than the 1990 level. The results show an increase of 59% in the period from 2005 to 2020, compared to the goal set by Hong Kong, China’s government to reduce GHG emissions by 19%–33% in the same period. If the emissions from international transport are excluded, the projection shows a comparatively smaller increase of 29% in the same period (2005–2020). To meet the goal of Hong Kong, China’s energy policy, more efforts to implement the proposed fuel mix for the power supply system should be considered. If Hong Kong, China goes ahead with its proposal to import additional nuclear

generated power from mainland China, its emissions would be significantly reduced compared to our BAU case. The other option is to adopt cleaner coal technologies or carbon capture and storage (CCS) with coal-fired power plants to reduce their CO<sub>2</sub> emissions. Efficient coal technologies are discussed further in Volume 1, Chapter 13.

In 2035, international transport is expected to account for the largest share of total CO<sub>2</sub> emissions, at 58% or 76.4 million tonnes of CO<sub>2</sub>, followed by the electricity generation sector at 27% (35.7 million tonnes of CO<sub>2</sub>) and the industry sector at 8% (10.9 million tonnes of CO<sub>2</sub>).

Figure HKC7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table HKC1 below suggests the growth in Hong Kong, China’s GDP will be offset by a reduction in the energy intensity of GDP (improved energy efficiency and move to a service-oriented economy) and a minor reduction in the CO<sub>2</sub> intensity of energy (fuel switching from coal to natural gas).

Table HKC1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-1.1%	-1.0%	-0.3%	-0.3%	-0.2%
Change in Energy Intensity of GDP	0.5%	1.7%	-1.0%	-1.1%	-1.7%
Change in GDP	4.0%	4.0%	3.8%	3.7%	3.7%
<b>Total Change</b>	<b>3.3%</b>	<b>4.8%</b>	<b>2.4%</b>	<b>2.2%</b>	<b>1.7%</b>

Source: APERC Analysis (2012)

**CHALLENGES AND IMPLICATIONS OF BAU**

Overall, the economy of Hong Kong, China is expected to continue to grow healthily. However, such growth will depend on energy security, as Hong Kong, China relies on imports for most of its energy supply.

With its lack of fossil energy resources, the economy is heavily dependent on imported oil, gas and electricity, especially to supply the large energy demands from both international aviation and its

residential and commercial sectors. It is critical that Hong Kong, China improve its energy security, in particular to protect itself from fluctuations in the energy market. While the lack of indigenous resources means little can be done to improve the security of the supply of fossil fuels, electricity security could be greatly improved by ensuring the continuation of the contract with the Guangdong Daya Bay Nuclear Power Station. Although Hong Kong, China is almost entirely dependent on imported energy, the fact much of this energy is imported from mainland China, with which it has close political and economic ties, should help to reduce the risk of supply.

In terms of reducing its GHG emissions, the shift away from coal to gas for power generation will make a significant difference, but the reduction will not be enough to meet the goal set by the Hong Kong, China Government. Furthermore, the increasing energy demand, especially for electricity, will pose a more serious challenge to reducing the actual GHG emissions. The economy could help to reduce its GHG emissions by shifting to more imported electricity from nuclear or renewable energy sources, or by further increasing its energy efficiency at home. Government policies to increase vehicle fuel efficiency and to implement district cooling schemes should be continued, to further reduce the overall environmental impacts.

Further study of the future fuel mix proposed by the Hong Kong, China Government should be explored, to find a strategy to implement and potentially contribute to the reduction of GHG emissions.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Hong Kong does not have any natural gas reserves and it is highly unlikely that any resource will be found in the economy in the future. It is also

unlikely to be economic to replace coal in electricity generation with additional gas imports. Under BAU scenario, gas-fired power plants will account for more than 50% of electricity generation by 2035. Beyond this, Hong Kong, China has a long term policy to increase nuclear energy imports from mainland China. This policy is likely to be prioritized over gas power expansions.

For these reasons, the High Gas Scenario was not run for Hong Kong, China. Therefore, figures HKC8–HKC10 are not included here.

#### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

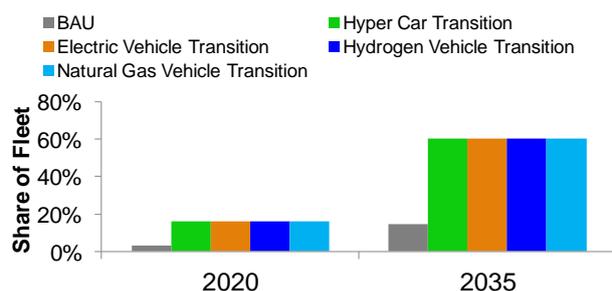
Hong Kong, China is already a compact city with high urban density and low energy consumption. Due to its natural geographical constraints, it would be impossible for Hong Kong, China to expand significantly in land area. For these reasons, the alternative urban development scenarios were not run for Hong Kong, China. Therefore, figures HKC11–HKC13 are not included here.

#### VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure HKC14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 15% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 85% in the BAU scenario.

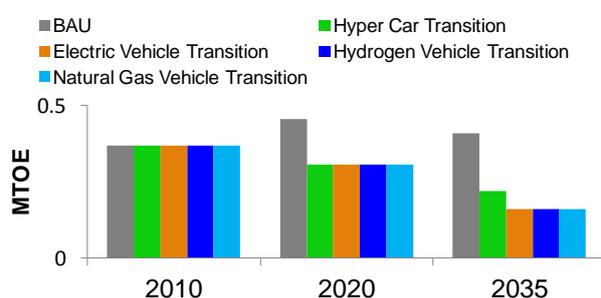
**Figure HKC14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure HKC15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 49% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—31% by 2035—even though these highly-efficient vehicles still use oil.

**Figure HKC15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



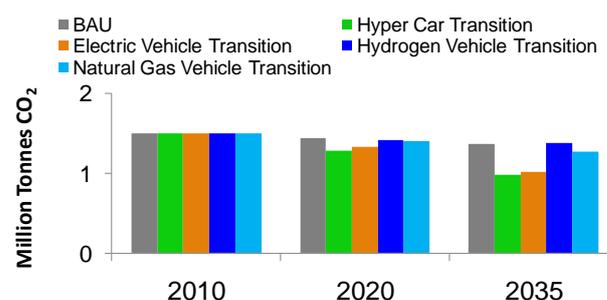
Source: APERC Analysis (2012)

Figure HKC16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Hong Kong, China, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions savings, with an emissions reduction of 28% compared to BAU in 2035. The Electric Vehicle Transition scenario is second, offering a 26%

emissions reduction compared to BAU. Compared to most economies, electric vehicles do relatively well in Hong Kong, China, reflecting the economy's heavy reliance on natural gas rather than coal for electricity generation, and the economy's relatively efficient electricity generation. Natural Gas Vehicle Transition offers a reduction of about 7% while the Hydrogen Vehicle Transition does not change emissions.

**Figure HKC16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# INDONESIA

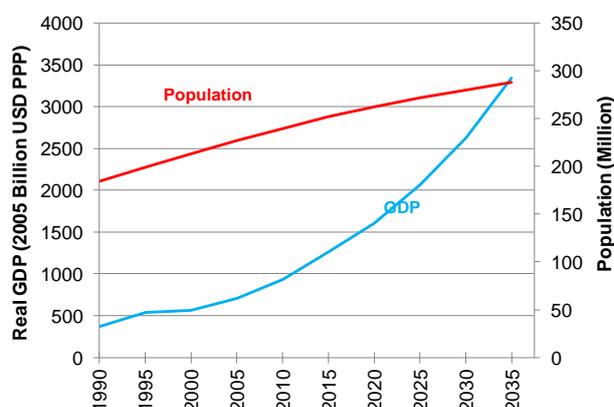
- Under business-as-usual assumptions that include strong economic growth, Indonesia's primary energy demand (including biomass) is projected to increase at an average annual rate of 3% over the outlook period, to reach 429 Mtoe in 2035. This is in line with the expected improvements in economic and living conditions spurred by the implementation of the Masterplan for Acceleration and Expansion of Indonesia Economic Development (MP3EI).
- Coal production is expected to continue a dominant role in the economy throughout the outlook period, with exports of coal rising to 333 Mtoe in 2035. Indonesia is already a net oil importer, and is expected to become a natural gas importer during the outlook period.
- CO<sub>2</sub> emissions will almost triple over the outlook period, reaching 1031 million tonnes of CO<sub>2</sub> by 2035. However, Indonesia's final energy intensity is predicted to decrease by 52% from 2005 levels.

## ECONOMY

The Republic of Indonesia is a large archipelago located south-east of mainland South-East Asia. The economy covers about 1 910 931 square kilometres of land. It is made up of five large islands—Sumatra, Java, Kalimantan, Sulawesi and Irian Jaya—and over 17 000 smaller islands, of which only 7% are permanently inhabited. The terrain is mostly coastal plains with mountainous interiors, and the climate is characteristically tropical with abundant rainfall, high temperatures and high humidity. Indonesia shares land boundaries with Malaysia, Papua New Guinea and East Timor.

The population of Indonesia in 2010 was estimated to be 239.9 million, making it the world's fourth most populous economy. About half of the population still lives in rural areas and are involved mainly in agriculture-related activities. The UN predicts that 60.3% of the population will be urbanized by 2025 (UNPD, 2012). Most of the urban population lives on Java Island, making it the most populous island in the world, congregating in Indonesia's capital city Jakarta as well as the cities of Surabaya, Bandung and Semarang.

Figure INA1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Indonesia was profoundly affected by the 1997 Asian financial crisis. The economy's GDP growth plummeted from 7.8% in 1996 to negative 13% in 1998. In the past five years, Indonesia has revived its economy to achieve consistent growth of about 6% annually, and was even able to stay resilient during the 2009 global financial crisis. In 2010, Indonesia had the largest economy in ASEAN, with overall GDP of USD 930.7 billion (in 2005 USD PPP), although the per capita GDP of USD 3880 (in 2005 USD PPP) is much lower than that of other ASEAN countries like Thailand (USD 7674 per capita) or Singapore (USD 51 800 per capita). This outlook expects Indonesia's GDP to increase at an average annual rate of 5% over the outlook period, reaching USD 3340 billion (in 2005 USD PPP) by 2035. In 2011, Indonesia gained an international investment grade credit rating and hit a record of USD 19.3 billion in foreign direct investment (Wall Street Journal, 2012), almost four times higher than the 2009 foreign direct investment of USD 4.87 billion (The World Bank, 2012).

However, poverty remains a challenge and the unemployment rate is still relatively high at 6.3% in 2012 (Jakarta Post, 2012c). Access to the basic services of electricity, water, sewage, transport, trade, education and health is still limited (IEA, 2008). For instance, in 2010 only 48% of households had sustainable access to improved drinking water, 52% to basic sanitation and the electrification ratio was at 67.2% (BAPPENAS, 2010; DGE, 2011). Furthermore, in the past decade, Indonesia has been beset by a string of natural disasters, including the massive tsunami in 2004, several major earthquakes registering over seven on the Richter scale, and the Mt Merapi volcanic eruption in 2010.

In order to meet its manifold challenges, in 2011 the Indonesian Government issued the Masterplan for Acceleration and Expansion of Indonesia Economic Development (MP3EI). The MP3EI

integrates three key objectives: to develop regional economic potential in six Indonesia Economic Corridors (Sumatra, Java, Kalimantan, Sulawesi, Bali-Nusa Tenggara, and Papua-Maluku Island); to strengthen economy-wide connectivity locally and internationally; and to strengthen human resource capacity and the economy's science and technology to support the development of programs in every economic corridor.

Indonesia's current economic structure is primarily focused on agriculture and industries that extract and harvest natural resources. With its vast natural resources, Indonesia has become a major global producer of a broad range of commodities. The economy is the world's largest producer and exporter of palm oil, and the second largest producer of coal, cocoa and tin. It is also a major producer of nickel, bauxite, steel, copper, rubber and fish products (CMEA, 2011). Under MP3EI, the economy aims to further develop its local resources to create a sustainable upstream and downstream activity chain; this includes biofuels and oleochemicals from palm oil, and tyres and gloves from rubber, as well as a steel-smelting industry from iron ore. To support the development of MP3EI's main economic activities, the Indonesian Government estimates a total investment of IDR 4012 trillion (USD 437 billion) (CMEA, 2011).

Indonesia's economic portfolio is fairly diverse. In 2010, the manufacturing sector accounted for the largest share of Indonesia's GDP at 24.82%, followed by the agricultural sector (15.34%), the mining sector (11.15%) and the services sector (10.19%) (MOI, 2011). Indonesia manufactures textiles and apparel, furniture, cement, fertilizer, steel and glassware. In the high technology area, Indonesia has the most sophisticated aircraft industry in South-East Asia and a growing range of automotive, shipping and electronic manufacturing capabilities. For instance, car manufacturers like Toyota, General Motors, Ford and Tata are not only increasing production in terms of output, but will also be rolling out new models to meet the increasing domestic demand (Jakarta Post, 2012a). The steel industry is also currently expanding its capacity, with several new steel mills expected to come online by 2015. These include the Krakatau Steel mill with an initial capacity of 3 million tonnes per year, the PT Meratus Jaya Iron Steel plant with production capacity of 315 000 tonnes per year and the PT Indoferro plant capable of producing 500 000 tonnes per year of steel billet (Kuo, 2012).

Vehicle ownership (excluding motorcycles) in this economy is still low at 79 vehicles per 1000 people (The World Bank, 2012). However, average annual growth of number of vehicles (excluding

motorcycles) in Indonesia is very high at about 11% annually, and this trend is expected to continue in the mid-term. Motorcycles are by far the most popular choice of vehicle in Indonesia, accounting for 79.4% of the 76.9 million vehicles registered with the State Police of Indonesia in 2010 (BPS, 2012).

Indonesia has a total of 355 856 km of roads, of which 57% are paved and 0.2% are toll roads (MOT, 2010). The economy's rail network is still underdeveloped. There are currently only four rail networks: one in Java, which is passenger oriented, and three in Sumatra, which are mostly used for transporting goods like coal, cement and palm oil (The World Bank, 2011). In the capital city of Jakarta, urban public transportation consists of a range of bus services including public minibuses operated by Metromini and Kopaja, public minivans, and the TransJakarta bus rapid transit (BRT) system, as well as two- and four-wheeled taxis. A rail-based mass rapid transit (MRT) system is also under development and is expected to commence operation in 2016.

As an archipelago, Indonesia relies heavily on air and sea transport for inter-island transportation. As of 2010, the economy has more than 300 ports scattered over the archipelago, and each of the major islands has at least one significant port city. While inland waterways are also used as transport routes, this is limited to the river systems in Eastern Sumatra and Kalimantan. The domestic airline network is quite extensive, providing quick and affordable access to areas not serviced by water and land transport networks.

The Indonesian Government recognizes that connectivity within the region is important to support economic activities; thus strengthening local and global connectivity is one of the four main strategies of the MP3EI. Roughly 10% of the IDR 4012 trillion (USD 437 billion) investment in MP3EI is directed toward basic infrastructure provision, such as roads, seaports, airports, railways and power generation (CMEA, 2011). This translates to increasing demand for energy in the form of fossil fuel and electricity in the coming years.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Indonesia has substantial coal and gas reserves but its oil reserves are depleting. According to the Handbook of Energy and Economic Statistics Indonesia 2011, as of January 2010, proven reserves of coal stood at 21.13 billion tonnes, proven reserves of crude oil at 4.23 billion barrels and proven reserves of natural gas at 3.07 trillion cubic metres (tcm) (108.4 trillion standard cubic feet) (ESDM,

2011, pp. 60, 66 and 78). At current production rates, Indonesia's coal reserves are sufficient for 77 years, oil reserves for 12 years and gas for 32 years.

About 60% of Indonesia's coal reserves are sub-bituminous while the rest are lignite coals (29%) and bituminous (11%) (Lucarelli, 2010). Kalimantan and Sumatra each holds roughly 49% of the coal reserves (CMEA, 2011); however, Kalimantan accounts for over 90% of Indonesia's coal production and export. This can be attributed to Kalimantan's higher quality coal, ease of extraction and transportation through navigable rivers and coastal areas, as well as its proximity to large power markets. Currently, about 20% of annual production is consumed domestically, while the rest is exported to coal-consuming countries like Japan, China, India, South Korea and other ASEAN countries (CMEA, 2011). Coal production in Indonesia is very attractive due to strong demand and strong reserves, and as such is projected to continue growing throughout the outlook period.

A very different situation can be observed in the Indonesian oil industry. Crude oil production has been on a downward trend for the past decade, culminating in Indonesia becoming a net oil importer in 2004. This can be attributed to natural maturation of producing oilfields combined with a slower reserve replacement rate and decreased exploration and investment in the industry. The economy actually has a fairly sizable oil reserve potential—the proven reserve in 2011 is 4.2 billion barrels, and out of the 128 estimated oil basins, only 38 have been extensively explored (PWC, 2011c). Most of the existing wells are in Sumatra and Kalimantan.

The Indonesian Government is promoting exploration further offshore and in frontier regions, providing incentives such as encouraging three-dimensional seismic surveys and agreeing to a change to the production-sharing contract—to increase oil companies' share from 15% to 35%. Other incentives also proposed include waiving land and building taxes as well as import duties for capital goods (Oil and Gas Technology, 2012). These incentives may improve Indonesia's oil outlook, but given that no new significant finds have been made in the past decade, and in the light of Indonesia's rapidly growing demand, the economy is expected to remain an oil importer in the long term.

Indonesia has the largest proven natural gas reserves in the Asia-Pacific region, estimated to be about 2% of the world's total estimated proven natural gas reserves (OGJ, 2011). The economy's major production sites are Arun in Aceh, Bontang in

South Kalimantan, and Tangguh in Papua (Jakarta Globe, 2011).

Indonesia's archipelago geography and the distributed nature of its gas reserves complicate the transportation process; this is mitigated through a combination of LNG facilities and a localized pipeline network (Hutagalung et al., 2011). Indonesia has three LNG liquefaction facilities in operation, one under construction in Donggi-Senoro and another planned at Abadi (Global LNG Info, 2012). In anticipation of rising domestic demand, especially from islands without their own natural gas sources, three regasification terminals will be constructed: the Nusantara LNG FSRU terminal, the East-Central Java LNG FSRU terminal, and the Lampung LNG FSRU terminal (Global LNG Info, 2012). In 2011, Indonesia exported its LNG to Mexico, Chile, China, Japan, South Korea, Chinese Taipei and Thailand (BP, 2012).

Indonesia's natural gas pipeline network is operated by the government-owned Perusahaan Gas Negara (PGN). It consists of high-pressure transmission pipelines totalling 2160 km in length, and a distribution pipeline network stretching more than 3500 km (PGN, 2012a; PGN, 2012b). Natural gas pipelines connect the economy to its neighbours Singapore and Malaysia, enabling pipeline gas exports to these economies. There are plans to further extend and interconnect the existing pipeline network so that eventually the islands of Sumatra, Java and Kalimantan will be linked via a 4184-km pipeline.

Maturing gas fields and rapidly increasing domestic demand are issues that have led the Indonesian Government to support the exploitation of several large pockets of natural gas, including the Abadi gas field in the Masela block (estimated 65 bcm (2.3 tcf) of gas) and the East Natuna block (estimated 1.3 tcm (46 tcf) of gas) (Jakarta Globe, 2012). There are initiatives in place to promote the extraction of coal bed methane (CBM) gas and shale gas. Indonesia has an estimated 12.8 tcm (453 tcf) of CBM in place, which is one of the largest resources in the world. CBM production started in March 2011 from the Sanga-Sanga PSC, and is being exported from the Bontang LNG facility (CBM Asia, 2012).

Indonesia also has the largest geothermal energy capacity in the world, estimated to be equivalent to 29 038 MW of electricity and spread across more than 270 locations (ESDM, 2011, p. 94). Geothermal energy is a special focus of Indonesia's USD 400 million Clean Technology Fund, which is co-financed by the World Bank and the Asian Development Bank. By 2011, 1.2 GW of thermal capacity had been successfully installed (PWC,

2011a). In addition to geothermal energy, Indonesia possesses a variety of renewable energy resources, including up to 75 670 MW of potential hydropower, 769 MW of potential micro-hydro and 49 810 MW of potential biomass, as well as solar, wind and uranium capabilities (BPPT, 2011).

Indonesia's power sector recently began to make meaningful investment after a decade of delay due to the extended impact of the 1997 Asian financial crisis. The initial priorities are to end severe power deficiencies in all the regions, and to improve electricity access from the current electrification ratio of 67% in 2010 to 99% by 2020. With these priorities in place, the Indonesian Government has mandated the government-owned electric company Perusahaan Listrik Negara (PLN) to implement fast-track programs to accelerate development of generating facilities.

Phase I of the 10 000 MW Accelerated Power Program was launched in 2006. PLN was required to build 9551 MW of new coal-based generation capacity by the end of 2009. Due to several reasons, the Indonesian Government delayed the final completion date for Phase I of the 10 000 MW Accelerated Power Program to 2014 (ESDM, 2012a). By the end of November 2012, 4520 MW of power generation capacity had been successfully completed and begun operation.

In 2010, the government mandated PLN to implement Phase II of the program. In this second phase, it is intended that PLN add 11 144 MW of capacity, based on 68% coal, 19% geothermal, 10% combined cycle gas, and 3% hydropower (ESDM, 2010). The two-phase accelerated power development program is expected to rapidly increase generating capacity, encourage renewable energy utilization, and at the same time eliminate oil-based power plants, except in regions where there are no other competitive alternative energy sources.

The composition of the generation capacity mix for the Phase II of the 10 000 MW Accelerated Power Program is updated as and when required to better ensure sustainability and energy security. In 2012, the Ministry of Energy and Mineral Resources (MEMR) has announced the 10 000 MW Phase II will add 10 047 MW capacity, of which 49% will be developed from geothermal, 30% from coal, 17% from hydropower, 3% from gas, and 1% from gassified coal (ESDM, 2012a).

Currently, Indonesia's power network consists of a central system connecting the islands of Java, Bali and Madura, as well as several isolated and partially interconnected systems on other islands. Plans are already in place to connect the partially integrated

power systems and isolated grids within the growing demand regions of Sumatra, Sulawesi, and Kalimantan. In 2012, PLN has begun initial construction for two transmission lines that will connect the Indonesia and Malaysia power grids. The first transmission line would be 122 km long, with a capacity of 275 kV, and will connect West Kalimantan to Sarawak in Borneo Island; it is expected to be completed by 2014. The second transmission line will be a 250-kV high voltage direct current (HVDC) subsea cable linking Sumatra to Peninsular Malaysia and is expected to begin operation in 2017 (Jakarta Post, 2012b).

## ENERGY POLICIES

Indonesia's current National Energy Policy (KEN for its acronym in Indonesian) was formulated under the Presidential Decree No. 5 of 2006. At the core of the KEN are several policies setting out five key objectives: diversification, rational energy pricing, energy conservation, energy sector reform, and rural electrification. KEN sets economy-wide targets for the optimal energy mix in 2025, with the aim of reducing oil's share while increasing the coal and renewable energy shares. KEN also established an economy-wide target to reduce the energy elasticity target to less than 1—in this case, energy elasticity is defined as the rate of change of total primary energy over rate of change of GDP.

The National Energy Council (DEN for its acronym in Indonesian) has been mandated to formulate and monitor the implementation of the KEN as well as to lead responses to energy crises and emergency situations. The immediate responsibility for regulating Indonesia's energy sector lies with the Ministry for Energy and Mineral Resources (MEMR) and its sub-agencies.

Indonesia's oil and gas industry is currently undergoing regulatory changes. The industry was reformed in 2001 under the Oil and Gas Law (Law No. 21/2001). BP Migas and BPH Migas were created as regulatory bodies for upstream and downstream activities, respectively. Exploration and production activities were conducted based on a fiscal contractual system that relies mainly on production sharing contracts (PSC) between government and private investors, which may include foreign and domestic companies, as well as the government-owned Pertamina.

However, on 13 November 2012, the Constitutional Court declared the existence of BP Migas was in conflict with the Constitution of 1945 and ordered the dissolution of BP Migas. As at the time of writing, the government is drafting a new Oil

and Gas Law that will determine the new industry structure. Until this law can be enacted, an Interim Working Unit for Upstream Oil and Gas Business Activities (SKSPMIGAS) has been established under MEMR to undertake all of BP Migas roles and responsibilities (ESDM, 2012b). SKSPMIGAS was later renamed to Working Unit for Upstream Oil and Gas Business Activities (SKKMIGAS) (ESDM, 2013).

The Indonesian mining sector is governed by the Constitution of 1945, which stipulates that Indonesia's natural resources are to be controlled by the government and must be used for the maximum benefit of the Indonesian people. Therefore, under the Law on Mineral and Coal Mining (Law No. 4/2009), the government holds the title to mining deposits and grants licenses for exploration and sale. The Mining Business Licenses are open to both Indonesian citizens and foreign investors who own Indonesian companies. To protect Indonesian interests, all license holders are required to pay production royalties to the government and to carry out coal processing and refining within Indonesia. License holders are also obligated to sell a percentage of coal production to the domestic market, which mostly consists of the power generation sector. This Domestic Market Obligation (DMO) percentage is determined annually by the MEMR, based on forecast domestic requirements. In 2010 the DMO percentage was set to 24.75%; in 2011 it was 24.17% (PWC, 2011b).

The industry was partially deregulated in 1985 when limited private participation in electricity generation was permitted in the form of Independent Power Producers (IPP). Electricity transmission and distribution remained a monopoly under the government-owned utility PLN, and IPPs were obliged to sell generated electricity exclusively to PLN. The new Electricity Law (Law No. 30/2009) enacted in September 2009, fully deregulated the power market by allowing IPPs to generate and sell electricity to end users. However, until 2011, PLN remained the sole owner of transmission and distribution assets and controlled over 80% of generation assets. The same law mandated central and regional government to regulate the electricity industry within their respective jurisdictions. This is done through these electricity regulatory authorities: the Directorate General of Electricity (DGE) and the Directorate General of New Energy, Renewable Energy and Energy Conservation (DGNREEC) under MEMR.

While subsidies on fuels for power generation and industry, and high-octane gasoline for transport, have been removed, substantial subsidies remain for

lower-octane gasoline and diesel oil for transport, kerosene and a certain class of electricity use in households. In 2011, it was estimated that the Indonesian Government spent a total of IDR 137 trillion (USD 14.8 billion) on energy subsidies, including fuel and electricity subsidies (IISD, 2011). The Indonesian Government is making progress towards fuel subsidy reforms; this includes significantly reducing kerosene subsidies through the kerosene-to-LPG program introduced in 2007.

In May 2012, the Indonesian President announced five policies under the National Saving Program that restricts access to subsidized fuel and introduces new energy diversification and conservation measures (Republika Online, 2012). The policies are:

1. Subsidized fuel consumption will be monitored through automated data collection at every fuelling station.
2. Government vehicles will be prohibited from using subsidized fuel.
3. Vehicles owned by plantation and mining owners will also be banned from using subsidized fuel.
4. Natural gas will be introduced as an alternative fuel in the transportation sector; as a start 33 natural-gas fuelling stations will be constructed and 15 000 converter kits will be distributed to launch the program.
5. Water and electricity savings measures will be implemented at the central and district offices (BUMN and BUMD for the acronyms in Indonesian) as well as in street lighting.

A more comprehensive strategy is being formed to gradually phase out all fossil fuel subsidies while minimizing the social impact of that change (IISD, 2012).

The Indonesian Government is also looking at further reducing the effect of fuel subsidies by developing alternative fuels for transportation. To drive this initiative, Ministerial Regulation No. 32/2008 was enacted regarding the Supply, Use and Commerce of Bio-fuels as Other Fuel. This makes biofuel consumption mandatory from 2009 (APEREC, 2011). So far, the initiative has been quite successful; as of 2010, there are several biofuel producers in the economy, capable of producing 4 506 629 kilolitres of biodiesel and 286 686 kilolitres bioethanol annually (DGNREEC, 2012).

In 2009, during the G20 Finance Ministers and Central Bank Governors Summit at Pittsburgh and the COP15 forum in Copenhagen, Indonesian President Yudhoyono pledged to voluntarily and

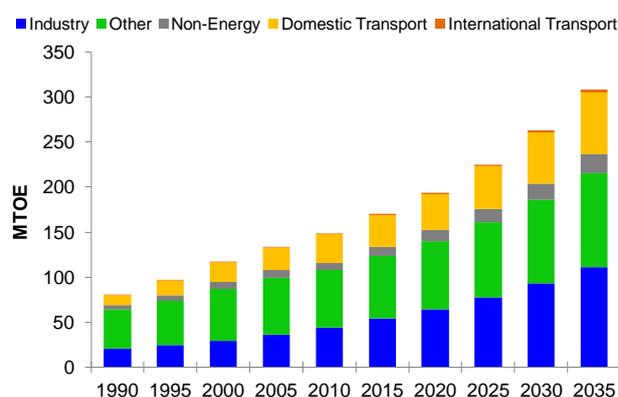
unilaterally cut carbon emissions by 26% relative to business-as-usual levels by 2020. Further emissions reductions of 41% are expected with international support (MOE, 2010). In line with this pledge, Indonesia's DEN is currently drafting a revised National Energy Policy (KEN). Early drafts propose that Indonesia will no longer build oil-fired power plants (ESDM, 2012c) and the renewable energy share of total primary energy consumption will be increased to around 25% by 2025, compared to the original target of 10% (Balia, 2011). The new policy also sees a paradigm shift to demand-side management with more emphasis on energy conservation to improve energy utilization. Through energy conservation measures, the DGNREEC expects to achieve a 17% reduction in final energy consumption by 2025, compared to consumption in 2009 (DGNREEC, 2012).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Indonesia's final energy demand under business-as-usual (BAU) assumptions is projected to increase at an average annual rate of 3% over the outlook period to reach 305 Mtoe in 2035 (International transport sector was excluded from this total). Demand is expected to increase across all sectors and all fuel types, with the exception of new renewable energy (NRE).

Figure INA2: BAU Final Energy Demand

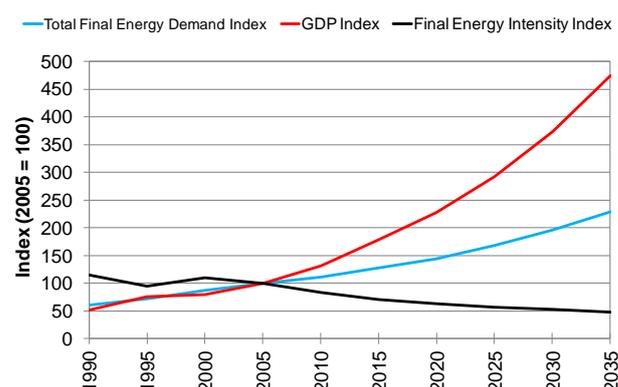


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to halve by 2035 compared to the final energy intensity in 2005. This is a positive indicator of the improving economic performance and better management of energy utilization in Indonesia.

Figure INA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Based on current trends for capacity and productivity expansion in Indonesia, industrial energy demand in the economy is projected to experience strong growth, almost tripling from 43.3 Mtoe in 2009 to over 110 Mtoe in 2035. Each type of fuel experiences similar rates of growth from 2010 to 2035 (of about 3–5%), with the exception of NRE, which will decline from 6.5 Mtoe in 2009 to 3.8 Mtoe in 2035. This indicates that as Indonesia's industrial sector becomes more sophisticated, biomass will be replaced by other commercial fuel like electricity and natural gas. Industrial energy intensity is projected to reduce by 36% from 2005 to 2035.

### Transport

Road vehicle ownership in Indonesia is far from saturation level, and given the economy's accelerating economic development, growth in vehicle ownership is expected to be very rapid. This will translate to a corresponding increase in energy demand in the transport sector. The same increasing energy demand growth can be expected in other types of transportation. In total, rail, road, aviation and water-based transportation will require about 71 Mtoe of energy by 2035, compared to 32 Mtoe in 2009. In 2009, virtually all of this demand was for oil, but with the introduction of alternative fuels and vehicles in the economy, demand for other fuels will gradually increase throughout the outlook period. By 2035, demand for other types of fuel will account for about 4% of the total demand. The gradual shift to more efficient fuel and transportation modes will contribute towards the expected 40% improvement in transportation energy intensity from 2010 to 2035.

### Other

The 'other' sector (combining the agricultural, commercial and residential sub-sectors) is expected to

experience strong growth in the 25 years from 2010 to 2035, given Indonesia's rapidly increasing economic and population growth. Each year should see an average growth of about 2% in the 'other' final energy demand, rising from 63.7 Mtoe in 2009 to 104 Mtoe by 2035.

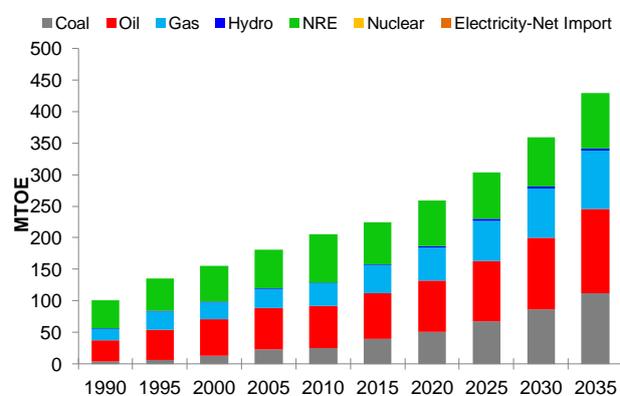
The demand will be primarily for NRE in the form of biomass, and for electricity and oil. This projection assumes that PLN is able to realize its target of improving the electrification ratio from 67.2% in 2010 to 99% in 2020. As a result, growth in electricity demand is expected to be the most rapid, at an annual average of 6%, as access to electricity will be complemented by increasing use of electrical appliances in both the commercial and residential sectors.

Energy intensity in the 'other' sector will improve significantly during the outlook period, achieving a 65% reduction from the 2005 to 2035. This can be attributed to the various energy efficiency and conservation measures currently in place in Indonesia. This includes the formation of government-owned service companies (ESCO); publication of energy benchmark and best practice guides for energy use in commercial buildings; updating of energy standards and labelling system for electrical appliances; subsidization of an energy-efficient lighting program in the residential sector; and promotion of research and development in energy efficiency and conservation.

### PRIMARY ENERGY SUPPLY

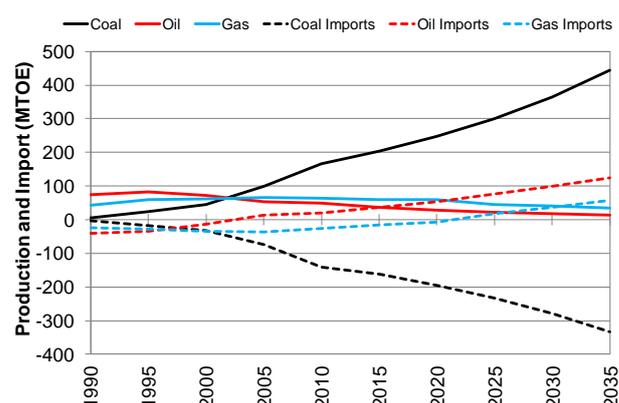
Indonesia's primary energy supply is expected to more than double during the outlook period, reaching 429 Mtoe in 2035. In 2035, the fuel mix will mostly be distributed among four fuels—oil (31%), coal (26%), natural gas (22%) and NRE (20%).

Figure INA4: BAU Primary Energy Supply



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure INA5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Indonesia will continue to produce coal, oil and gas; however, by the latter half of the outlook period, oil and gas production will begin to dwindle. Indonesia became a net oil importer in 2004, and unless new, viable natural gas resources can be developed, Indonesia will begin to import natural gas after 2020. On the other hand, given its substantial coal reserves and established coal industry, Indonesia will remain a major coal exporter throughout the 2010–2035 period.

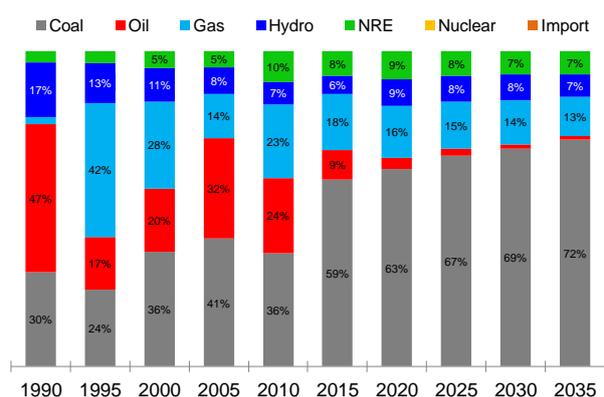
### ELECTRICITY

Indonesia's electrification ratio and per capita electricity consumption were pretty low in 2010 at 67.2% of total households and 620 kWh per capita respectively (DGE, 2011, p. viii). There is much room for growth, and considering that annual electricity consumption growth has been high at 6–7%, it is not surprising Indonesian authorities have embarked on the two-phase 10 000 MW Accelerated Power Program to meet this anticipated surge in electricity demand.

This huge influx of capacity rapidly shrinks oil's share in power generation from 24% in 2010 to 1% by 2035. Coal and gas are the preferred investment choices for thermal power plants, especially coal since Indonesia has vast but under-utilized coal deposits. This will lead to coal dominating the generation mix from 2015 onwards.

In line with Indonesian government programs, it is projected that NRE (in the form of solar, wind, geothermal and biomass) will contribute an increasing share to the generation mix over the outlook period, reaching 7% by 2035. Most of this contribution will be from geothermal power plants, in which Indonesia has significant potential (estimated about 29 GW).

Figure INA6: BAU Electricity Generation Mix

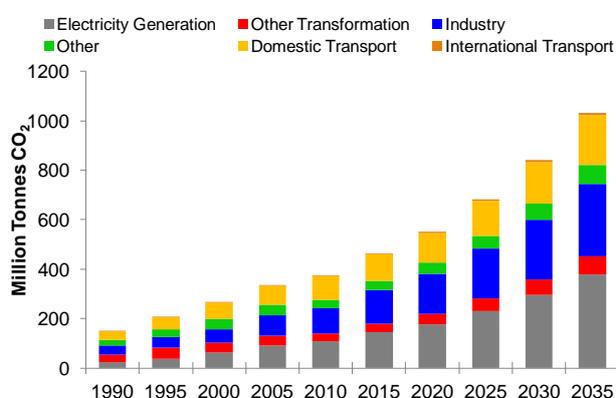


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

## CO<sub>2</sub> EMISSIONS

Over the outlook period, Indonesia's CO<sub>2</sub> emissions from combustion of fossil fuels is projected to reach 1031 million tonnes of CO<sub>2</sub> in 2035, which is a 175% increase from 2010 emission levels. Fossil-fuel-based electricity generation is expected to be the main source of CO<sub>2</sub> emissions, followed by the industrial and domestic transport sectors.

Figure INA7: BAU CO<sub>2</sub> Emissions by Sector

Source: APERC Analysis (2012)

Table INA1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	1.5%	-0.1%	1.0%	0.9%	1.1%
Change in Energy Intensity of GDP	-0.5%	-3.0%	-2.5%	-2.3%	-2.1%
Change in GDP	4.4%	5.7%	5.4%	5.3%	5.2%
Total Change	5.5%	2.4%	3.8%	3.8%	4.1%

Source: APERC Analysis (2012)

The decomposition analysis illustrated in Table INA1 shows that Indonesia's CO<sub>2</sub> emissions are affected most by economic growth, and to a lesser degree by the change in CO<sub>2</sub> intensity of energy (as a result of fuel switching, especially to coal). The total increase in CO<sub>2</sub> emissions will be moderated by the

reduction in energy intensity of GDP (due to increased energy efficiency). The latter indicates overall better economic efficiency in terms of energy use.

## CHALLENGES AND IMPLICATIONS OF BAU

Under BAU assumptions, Indonesia will continue to experience strong economic growth, which will lead to rapidly increasing domestic energy requirements. Indonesia has ample indigenous resources of coal and geothermal, and plans are underway to effectively harness these resources to meet growing demand. It is projected that under existing policies, Indonesia will likely reduce its final energy intensity by half from 2005 to 2035; however, the absolute amount of carbon emissions will almost triple during the same period. There remain significant opportunities for improving environmental sustainability, particularly in the power generation, industry and transport sectors.

## ALTERNATIVE SCENARIOS

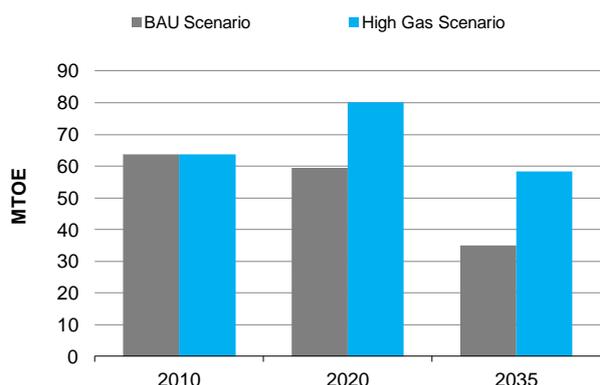
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Indonesia assumed the production increase shown in Figure INA8, which is 67% by 2035. Indonesia has ample natural gas resources, estimated to be the largest in the Asia-Pacific region, but limited technology and infrastructure for gas extraction and transport. For this High Gas Scenario, it was assumed that Indonesia was able to attract sufficient investment to overcome these challenges, which would spur construction of the necessary infrastructure and development of major gas projects such as the Natuna D-Alpha gas field. Note these estimates can be considered conservative as the potential for unconventional gas like shale gas and coal bed methane (CBM) was not included.

Figure INA8: High Gas Scenario – Gas Production

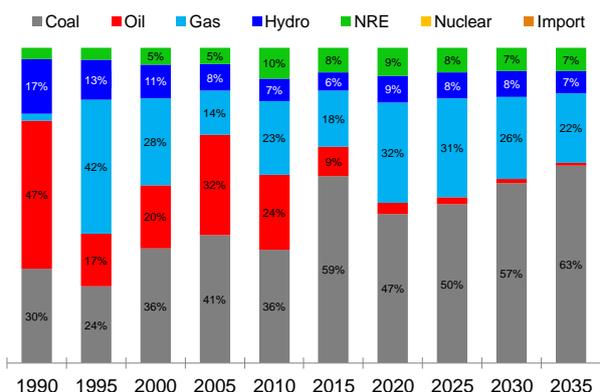


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. For Indonesia, the economy would likely export most of the additional gas produced as LNG to maximise economic benefits, while the remainder will replace coal to reduce local air pollution and CO<sub>2</sub> emissions.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure INA9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario shown in Figure INA6. It can be seen that the gas share has increased by 9% by 2035, while the coal share has declined by the same amount.

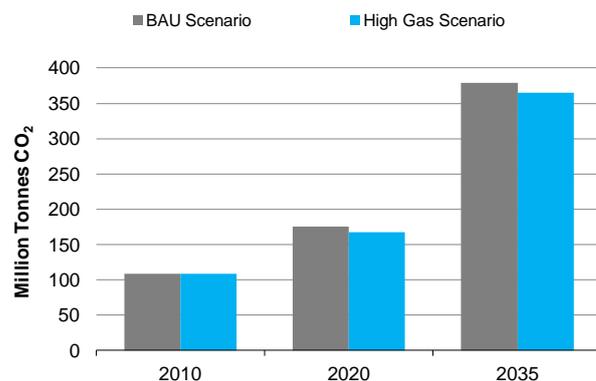
Figure INA9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions than coal per unit of electricity generated, this reduces CO<sub>2</sub> emissions in electricity generation by 3.8% in 2035. Figure INA10 shows this CO<sub>2</sub> emission reduction.

Figure INA10: High Gas Scenario –CO<sub>2</sub> Emissions from Electricity Generation



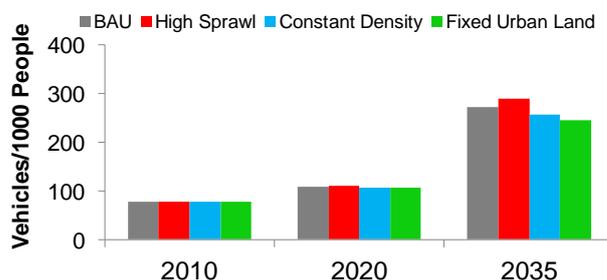
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure INA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The impact of urban planning on vehicle ownership is relatively small. Since vehicle ownership is well below saturation level, vehicle purchasing will continue to grow almost regardless of urban planning. By 2035, vehicle ownership is about 6% higher in the High Sprawl scenario compared to the BAU, and about 10% lower in the Fixed Urban Land scenario.

Figure INA11: Urban Development Scenarios – Vehicle Ownership

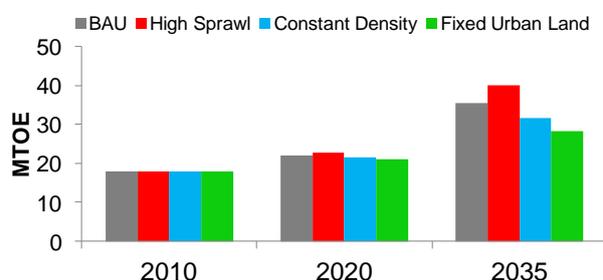


Source: APERC Analysis (2012)

Figure INA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Better urban planning has a more pronounced impact on light vehicle oil consumption than on vehicle ownership because compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil

consumption would be 13% higher in the High Sprawl scenario compared to BAU in 2035, and about 20% lower in the Fixed Urban Land scenario.

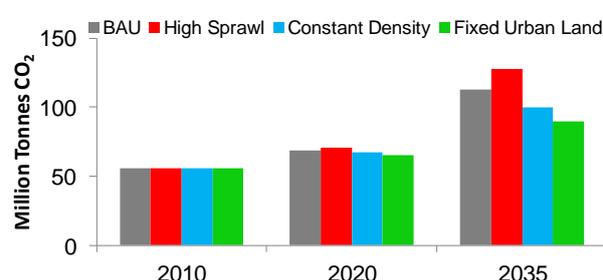
**Figure INA12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure INA13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure INA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



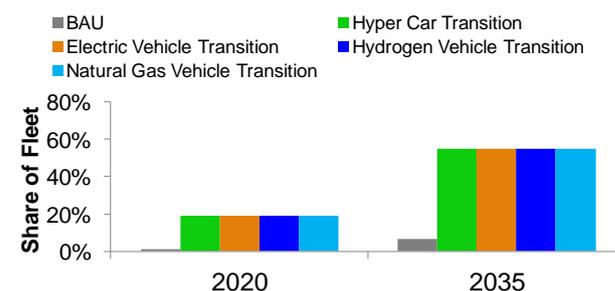
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure INA14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of the alternative vehicles in the fleet reaches around 55% compared to about 6% under BAU. The share of conventional vehicles in the fleet is therefore only about 45%, compared to about 94% in the BAU scenario.

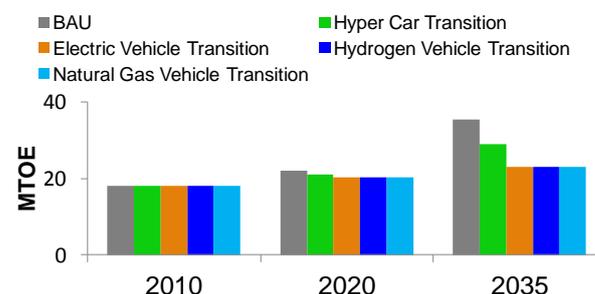
**Figure INA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure INA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 36% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU in 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 23% by 2035—even though these highly efficient vehicles still use oil.

**Figure INA15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

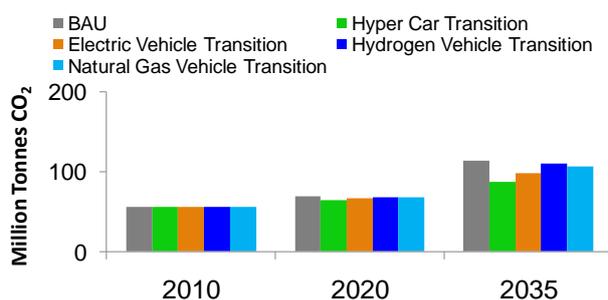
Figure INA16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Indonesia, the Hyper Car Transition scenario is the winner in terms of CO<sub>2</sub> emissions reduction, with an emission reduction of 23% compared to BAU in 2035. The Electric Vehicle Transition, Natural Gas Vehicle Transition and Hydrogen

Vehicle Transition scenarios offer lower emission reductions (13%, 6% and 3% respectively).

Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels: electricity for electric vehicles, hydrogen for hydrogen vehicles and gas in natural gas vehicles. The additional demand for electricity and hydrogen generation would produce more CO<sub>2</sub> emissions and this offsets some of the benefits gained from oil replacement.

**Figure INA16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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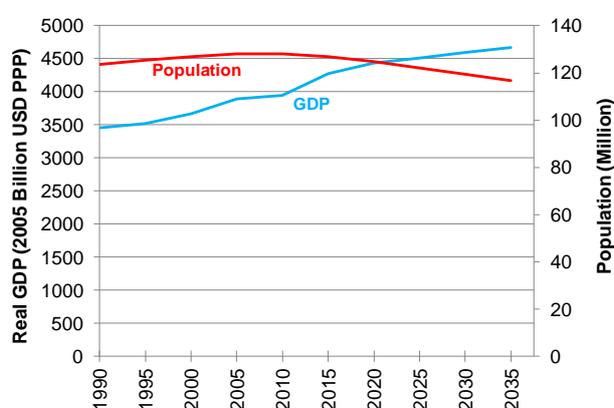
# JAPAN

- Japan's final energy consumption is expected to decrease at 0.6% per year over the outlook period as a result of Japan's slow GDP growth and declining final energy intensity.
- The future of nuclear power remains the largest uncertainty in Japan's energy outlook, as Japan has not yet reached a consensus on the role of nuclear power after the accident at the Fukushima Daiichi Nuclear Power Plant in March 2011. This Outlook assumes no new nuclear units are built, and that existing nuclear units will continue to operate, but will be phased out at the end of their 40-year life. The Japanese Government is considering three options for how much nuclear energy will contribute to the power generation mix in 2030, namely 0%, 15% or 20–25%, and has called for public comments on these options.
- Japan's CO<sub>2</sub> emissions are expected to decrease at 0.5% per year toward 2035, because of the decrease in final energy consumption and decline of final energy intensity.

## ECONOMY

Japan is located in East Asia and is made up of several thousand islands, the largest of which are Honshu, Hokkaido, Kyushu and Shikoku. It has a land area of about 377 800 square kilometres, most of it mountainous and thickly forested. In 2010 the population was 128.1 million people and the population density was 339.1 people per square kilometre.

Figure JPN1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Japan's population is expected to decrease to 117 million by 2035 (the annual average growth rate is decreasing at 0.4% for the period). In 2010 about 40% of the total population was concentrated in Tokyo Metropolitan Area and Kansai (Osaka, Kobe and Kyoto) Areas. The urbanization rate was 77.3% in 1990 and reached 90.5% in 2010. The urbanization rate is expected to reach 96.3% in 2025 (UN, 2012).

Japan's GDP per capita increased at an annual rate of 0.5% from USD 27 999 (2005 USD PPP) in 1990 to USD 30 807 in 2010. It is expected to increase at an annual rate of 1.1% from USD 30 807 in 2010 to above USD 40 000 in 2035. This low rate

of annual growth of GDP can largely be explained by three factors:

- aging population combined with the diminishing number of children (decrease in domestic consumption)
- mature social infrastructure (decrease in domestic investment)
- relocation of production sites overseas by Japanese companies (decrease in export and increase in import).

Japan has diverse regional climates. On the Pacific Coast, summers are often rainy, while winters are generally dry; temperature averages are higher in the southern regions and lower in the north. On the coast of the Japan Sea, there is a lot of heavy snow in winter. In the Okinawa islands, off the coast of Kyushu, the climate is subtropical or tropical, with high temperatures throughout the year. In general, Japan faces heavy demands for electricity in summer (for cooling) and in winter (for heating).

In Japan, the major industries are iron and steel, chemical and petroleum, machinery, and non-metallic minerals. The share of final energy consumption by these four industries is about 65% of the total industry demand in 2009 (IEA, 2011). The iron and steel industry consume mainly coal and electricity, whereas the chemical and petroleum industry consume mainly oil products and electricity. These four major industries are expected to continue to play important roles into the future.

Road transport accounted for 66% of Japan's passenger-kilometres in 2012 (IEEJ, 2012, pp. 130–131). Japan has an extensive network of about 1.3 million kilometres of roads, including about 9000 kilometres of national expressway. Japanese roads are generally paved and well maintained (MLIT, 2012b).

Railways account for an unusually large share of passenger-kilometres at 29% (IEEJ, 2012, pp. 130–131). Japan is well known for its network of ‘bullet trains’ (*Shinkansen*) that provide high-speed service between major cities. All major Japanese cities have local railway and/or subway systems. Air transport accounts for most of the remaining non-road, non-rail domestic passenger-kilometres.

In freight transportation, road transport accounts for 64% of the tonne-kilometres. Water-based transport, mostly coastal shipping, accounts for another 32%. Japan has 23 ‘Specially Designated Ports’, 105 ‘Major Ports’, and many more small and medium-sized ones (MLIT, 2012a). In contrast to the large role of rail in passenger transport, freight transport by rail accounts for only about 4% of the freight tonne-kilometres (IEEJ, 2012, pp. 130–131).

Almost 99% of the passenger and freight vehicles used in Japan in 2009 were domestically produced. On the other hand, about 55% of the motorcycles in use in 2009 were domestically produced (MLIT, 2010 and MOF, 2010).

## ENERGY RESOURCES AND INFRASTRUCTURE

Japan has very limited fossil fuel energy resources. Japan produces coal, crude oil and natural gas on a very small scale compared to its demand. Import dependency in 2009 for coal was 99%, crude oil almost 100%, and natural gas 96% (APEC, 2009).

Japan has no pipeline or electrical connections to other economies. All natural gas is imported in the form of LNG. Japan had 27 LNG receiving terminals as of 2009, with a total storage capacity of 15.09 million kilolitres. This is equivalent to about 9% of the total annual LNG import volumes. Japan will have seven more LNG receiving terminals by 2015 (JIE, 2011).

Japan has confirmed resources of methane hydrates equivalent to 1.1 trillion cubic metres of methane gas (about 1000 Mtoe) in the eastern Nankai Trough area. However, further research will be required before this resource can be developed. Japan started the Methane Hydrate Development Program in 2001 in order to utilize resources in the coastal waters of Japan. The program consists of three phases and will be completed in 2018 (METI, 2001).

Japan generated 1041.0 TWh of electricity in 2009. The sources of electricity generation are: coal 279.5 TWh (26.8%), oil 91.6 TWh (8.8%), gas 284.9 TWh (27.4%), hydro 75.2 TWh (7.2%), new renewable energy 30.0 TWh (2.9%), and nuclear 279.8 TWh (26.9%). Japan had 54 commercial

nuclear units with about 49 GW of capacity prior to the Fukushima Nuclear Accident in March 2011 (IEEJ, 2012, p. 208). However, as discussed in the next section, all but two of these units were shut down at the time this Outlook was compiled.

Japan has already developed almost all of the sites suitable for large-scale hydro power plants. Therefore, hydro development must concentrate on sites suitable for small and medium-scale plants.

Japan has significant potential sources of renewable energy. These are as follows (NPU, 2011):

1. *Solar photovoltaic*
  - Residence: 91 GW
  - Non-residence:
    - Public buildings, other commercial and industry: 44 GW
    - Little-used and unused land (e.g. waste disposal sites, transport right-of-ways): 18 GW–39 GW
    - Fields and rice paddies that have been abandoned and are no longer cultivated: 3 GW–104 GW
2. *Wind*
  - Onshore: 290 GW
  - Offshore: 1500 GW
3. *Small and medium-sized hydro*: 20 GW
4. *Geothermal*
  - Hot water resources: 4.3 GW
  - Hot springs: 0.72 GW
5. *Biomass*: 0.73 GW.

There are constraints that may hinder the development of some of these resources. Most geothermal energy resources are in national parks where strict environmental rules and regulations may prevent or severely limit development. Biomass energy development must take into account competition for land with food supply, as well as potential environmental impacts.

## ENERGY POLICIES

In 2007, the Japanese Government announced ‘Cool Earth 50’, a cooperative initiative with major greenhouse gas emitters to reduce worldwide emissions by 50% from current levels by 2050 (METI, 2008a). At the United Nations Summit on Climate Change in September 2009, the Japanese Prime Minister pledged that Japan would cut its greenhouse gas emissions by 25% from 1990 levels by 2020, provided that a fair and effective international framework, in which all major economies participate, had been established.

The Strategic Energy Plan, which was last revised in 2010, aims to fundamentally change the energy supply and demand system. It set these ambitious targets for 2030 (METI, 2010):

1. Doubling the energy self-sufficiency rate (18% in 2010) and the ratio for the self-developed fossil fuel supply (resources developed abroad by Japanese petroleum and gas companies, which were 26% in 2010), thereby raising Japan's 'energy independence ratio' to about 70% (38% in 2010).
2. Raising the ratio of zero-emission power sources (mainly nuclear) to about 70% (34% in 2010).
3. Halving CO<sub>2</sub> emissions from the residential sector.
4. Maintaining and enhancing energy efficiency in the industrial sector at the highest level in the world.
5. Maintaining or obtaining leading shares in global markets for energy-related products and systems.

However, after experiencing the Great East Japan Earthquake and Fukushima Nuclear Accident in March 2011, the Japanese Government decided to review the Strategic Energy Plan. This review process is underway at the time of writing, with the key issue being the share of nuclear power in the power supply mix, as discussed below.

Japan has a Law on the Rational Use of Energy (an energy conservation law). This law requires business organizations (such as manufacturers and service companies) with energy use equivalent to 1500 kilolitres or more per year of crude oil, to report annually on the amounts of energy they consume and to prepare and submit medium-term (3–5 years) plans for the rational use of energy, and to assign responsible people to energy management. The target for reducing energy consumption intensity is 1% or more per year on average over the medium term (APERC, 2011). Japan has no fossil fuel subsidies that would encourage wasteful consumption.

Japan has a Top Runner Program to improve energy efficiency of machinery and equipment. This program sets standard target values for energy-using machinery and equipment, and calls for manufacturers and importers to, on average, meet this standard in their products. Currently, 23 categories of products are designated in the program (APERC, 2011).

Japan's Building Energy Codes define two categories of buildings for their targets: Type 1 House/Building (with floor area of 2000 square metres or more), and Type 2 House/Building (with

floor area of 300–2000 square metres). Owners of these types of houses and buildings are required to report their energy conservation measures prior to construction, and afterwards to report the state of maintenance of the house or building to the relevant authority regularly (every three years). For the Type 1 House/Building, penalties may be levied if the building is not able to achieve satisfactory energy performance (APERC, 2011).

In the transport sector, large common carriers (rail, truck, bus, taxi, ship, and air) are required to annually prepare and submit energy conservation plans, as well as an annual report on their energy consumption. Similar rules apply to organizations that privately travel 30 million tonne-kilometres per year of their own freight (APERC, 2011).

Japan has a tax incentive scheme to promote the purchase of energy-efficient equipment. When small and medium-sized companies purchase specified energy-conserving equipment, they are given a tax credit. Companies of all sizes are given a special depreciation allowance on purchase of the specified equipment (APERC, 2011).

Japan has a vehicle-greening tax scheme and an eco-car tax reduction scheme; these provide tax incentives for owners of low-emission and/or high-fuel-efficiency vehicles. At the same time, heavy taxes are levied on older vehicles that are becoming harmful to the environment (APERC 2011).

Japan will grant direct subsidies for several types of efforts promoting energy efficiency:

- to support business operators who introduce 'highly significant' energy-saving facilities
- to introduce high-efficiency energy systems in homes/buildings or building energy management systems (BEMS)
- for research and demonstration projects to develop energy conservation technology (APERC, 2011).

Since Japan has very scarce domestic oil and gas reserves, the Japanese Government has given financial support for oil and gas exploration, development and production outside Japan through the Japan Oil, Gas and Metals National Corporation (JOGMEC). This has taken the form of investment and loan guarantees to project companies. In November 2011 there were 135 Japanese oil and gas companies engaging in exploration and development of crude oil and natural gas in 41 economies. The share of equity crude oil and natural gas to total imports is 23% in 2009 (JPDA, 2011).

Japan has 10 vertically integrated, mainly privately owned General Electricity Utilities, which have traditionally managed generation, transmission and distribution of electricity on a regulated monopoly basis. In addition, Wholesale Electricity Utilities operate large power plants and sell the output to a General Electric Utility. With the gradual liberalization of the Japanese power market since 1995, three new types of firms have entered the market: Wholesale Suppliers such as Independent Power Producers, which sell electricity to a General Electric Utility on a smaller scale than a Wholesale Electric Utility; Power Producers and Suppliers, who sell electricity directly to large customers using a transmission wheeling service provided by a General Electric Utility, and Specified Electricity Utilities which generate, transmit and distribute electricity directly to customers using their own network.

Customers with contract volumes of less than 50 kW are still categorized as ‘regulated’. On the other hand, customers with contract volumes of 50 kW or more are categorized as ‘de-regulated’, and may purchase their electricity from either their General Electric Utility or a Power Producer and Supplier (TEPCO, 2012).

Japanese gas utilities also have historically operated as regulated monopolies. They are mainly privately owned, although some are municipally owned. As with electric utilities, the market has been partially liberalized since 1995 (METI, 2008b). De-regulated gas customers negotiate with gas companies on prices, while regulated customers pay regulated prices. Since 2007, customers with consumption volumes of more than 100 000 cubic metres per year were de-regulated (METI, 2008b).

Japan’s Nuclear Energy Policy is currently under review after the Fukushima Nuclear Accident. Over the months after the accident, each of the nuclear units still in operation in Japan was shut down for scheduled inspection—this is required by law at least once every 13 months. After the inspection shutdowns, the companies did not restart operations for two reasons. First, the then Prime Minister Naoto Kan announced the government would carry out additional ‘stress tests’ for confirming the safety of nuclear power plants. Secondly, the power companies could not easily get agreements to restart from the local governments where the nuclear power plants were located. (Although agreement from the local government is not stipulated in Japanese regulations as a necessary condition for restart of a nuclear power unit, in practice the power companies cannot ignore the will of the local governments.)

By early May 2012, all 50 remaining nuclear power units (four units of the Fukushima Daiichi Nuclear Power Plant were decommissioned in April 2012) had ceased operation; that meant no electricity was being generated from nuclear power. Without nuclear power, there was concern that Japan would experience power shortages and blackouts during the summer of 2012 (from July to September). In July 2012, then Prime Minister Yoshihiko Noda announced the restart of two units of the Ohi Nuclear Power Plant. That decision, along with stringent electricity conservation efforts, allowed Japan to make it through the summer of 2012 without major disruptions to electricity service.

Over the longer term, Japan continues to face much controversy over the future of nuclear power. The Japanese Government is considering three options for how much nuclear energy will contribute to the power generation mix in 2030, namely 0%, 15% or 20–25%, and has called for public comments on these options (EEC, 2012).

In September 2012, a Nuclear Regulation Authority was established with the aim of integrating several nuclear safety authorities, while achieving separation of nuclear safety regulation and nuclear energy promotion. The government has emphasised that the rules regarding the 40-year limitation of the operation of nuclear power plants will be strictly applied (NPU, 2012). This means that unless there is new construction of nuclear power plant units, Japan will phase out all nuclear power by the end of 2049.

For the purposes of this Outlook, APERC assumed the existing nuclear units would resume operation once current safety reviews were completed, but each unit would be decommissioned at age 40 and there would be no newly built nuclear power units. The net effect of these assumptions is a gradual phase-out of nuclear power in Japan. APERC has also assumed that natural gas, coal and new renewable energy, such as wind, solar, biomass and other, would compensate for the decrease in electricity generation from nuclear energy. The current uncertainty regarding nuclear power is probably the largest uncertainty affecting Japan’s business-as-usual energy outlook.

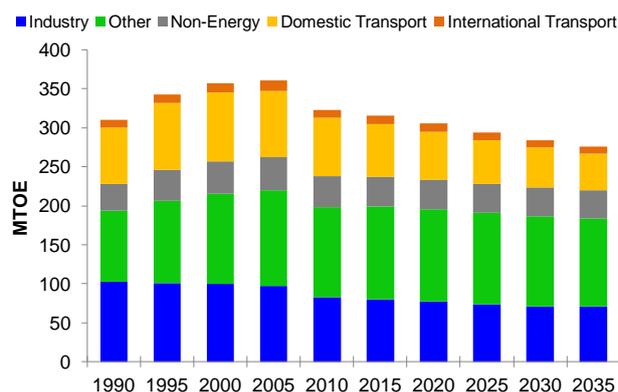
## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Japan’s business-as-usual (BAU) final energy demand is expected to decrease at 0.6% per year over the outlook period (from 323.0 Mtoe in 2010 to 276 Mtoe in 2035). This decrease in final energy demand is caused by the slow growth of Japan’s GDP and a decline in final energy intensity. The

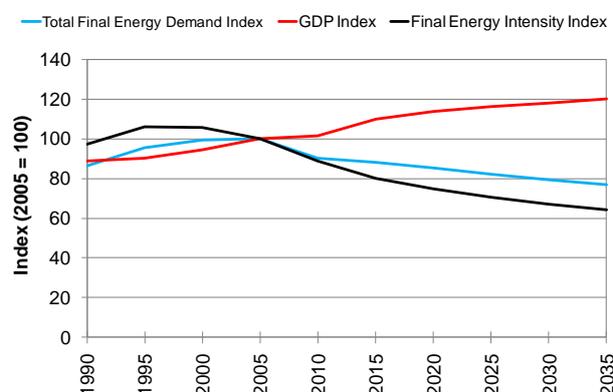
industry sector’s share of the demand is expected to be about the same in 2010 and 2035, roughly 26%. However, the share taken up by the ‘other’ sector (which includes residential and commercial) is expected to increase from 36% in 2010 to 41% in 2035. The domestic transport share will decrease from 23% in 2010 to 17% in 2035. Final energy intensity is expected to decline by about 36% between 2005 and 2035.

Figure JPN2: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Figure JPN3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Final energy demand in the industrial sector is projected to decrease at 0.6% per year, from 83 Mtoe in 2010 to 71 Mtoe in 2035. Slow GDP growth, relocation of production overseas by Japanese companies and improvement of energy efficiency are the reasons for the decrease.

### Transport

Final energy demand in the domestic transport sector is projected to decrease at 1.8% per year, from 75 Mtoe in 2010 to 47 Mtoe in 2035. Improvement in

vehicle energy efficiency contributes significantly to the decrease in the final energy demand for transport.

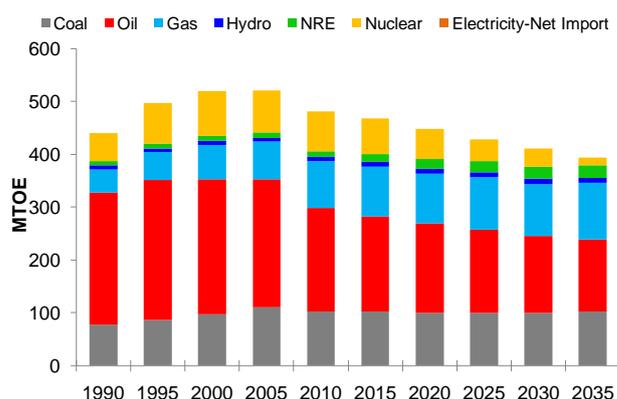
### Other

Final energy demand in the ‘other’ sector is projected to decrease at 0.1% per year, from 115 Mtoe in 2010 to 113 Mtoe in 2035. Growing demand for various convenience appliances and equipment keeps energy demand from declining more quickly in this sector.

## PRIMARY ENERGY SUPPLY

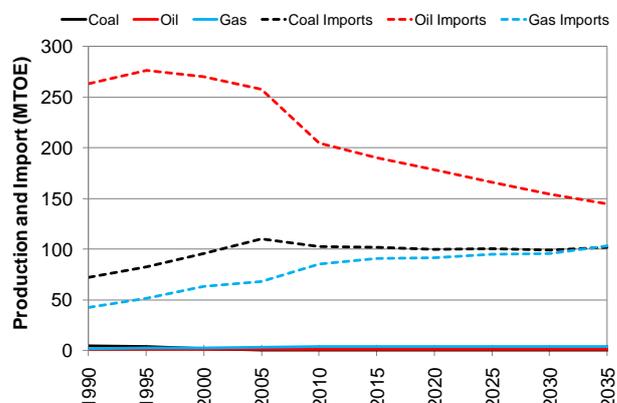
Japan’s primary energy supply is projected to decrease at 0.7% per year, from 480 Mtoe in 2010 to 394 Mtoe in 2035. The new renewable share of the primary energy supply is projected to increase at 3.3% per year, while the nuclear share is projected to decrease at 6.2% per year. Fossil fuels (coal, oil and gas) are still expected to maintain a dominant role in the primary energy supply in 2035. Primary energy intensity is expected to decline by about 37% between 2005 and 2035.

Figure JPN4: BAU Primary Energy Supply



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Figure JPN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

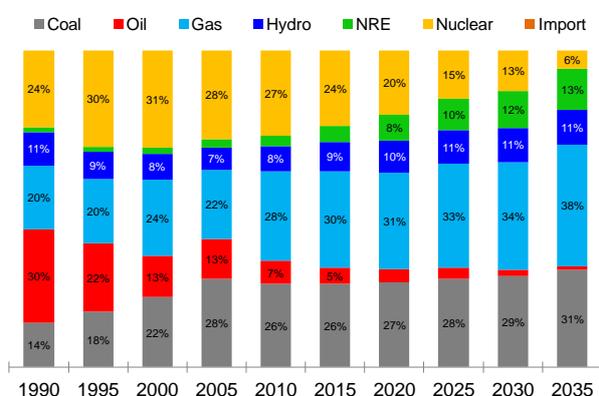
Both oil and gas production in Japan is expected to level off and then remain low throughout the period to 2035. While Japan has reasonable prospects of finding new oil and gas fields domestically, the economy faces depletion (decrease in production) of its existing oil and gas fields, and this would offset any increase in production from new fields.

Japan’s net energy imports (coal, oil and gas combined) are projected to decrease at 0.4% per year over the outlook period, reflecting the decrease in the primary energy supply. Japan will continue to seek to import more equity oil and natural gas from overseas.

**ELECTRICITY**

Japan’s BAU electricity generation is expected to decrease from 1071 TWh in 2010 to 1010 TWh in 2035; the average annual rate of this decrease is 0.2%. In 2010, coal, gas and nuclear are the main sources for electricity generation mix. Their share is 26%, 28% and 27% respectively. As discussed earlier, the share of nuclear is expected to decrease to 13% by 2035, while the share of coal and gas is expected to increase to 31% and 38%, respectively in 2035. The share of new renewable energy is expected to increase from 3% in 2010 to 13% in 2035.

*Figure JPN6: BAU Electricity Generation Mix*

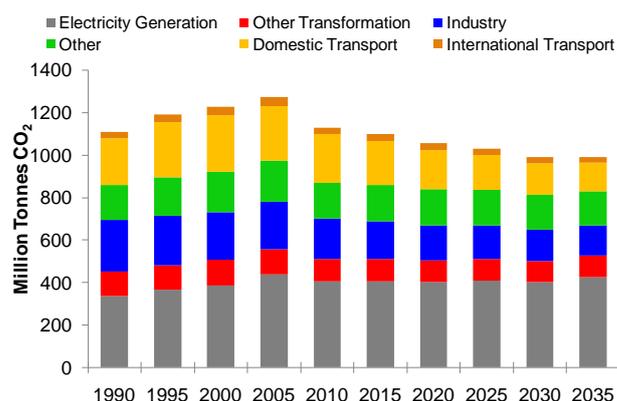


Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

**CO<sub>2</sub> EMISSIONS**

Japan’s BAU CO<sub>2</sub> emissions are projected to decrease at 0.5% per year, from about 1130 million tonnes of CO<sub>2</sub> in 2010 to 990 million tonnes of CO<sub>2</sub> in 2035. The decrease in the economy’s final energy consumption and decline of final energy intensity are the main reasons for the decrease in CO<sub>2</sub> emissions.

*Figure JPN7: BAU CO<sub>2</sub> Emissions by Sector*



Source: APERC Analysis (2012)

As shown in Table JPN1, Japan’s 2010–2035 change in CO<sub>2</sub> emissions will be driven by a 1.5% per year reduction in the energy intensity of GDP (improvements in energy efficiency and a shift toward less energy-intensive industry). This reduction will be offset by 0.7% per year growth in GDP and a 0.3% per year growth in the CO<sub>2</sub> intensity of energy (declining use of nuclear power). The net result will be a 0.5% per year decline in CO<sub>2</sub> emissions.

*Table JPN1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion*

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.2%	-0.7%	0.0%	0.1%	0.3%
Change in Energy Intensity of GDP	0.4%	-2.0%	-1.6%	-1.5%	-1.5%
Change in GDP	0.8%	0.3%	0.7%	0.6%	0.7%
Total Change	0.9%	-2.4%	-1.0%	-0.8%	-0.5%

Source: APERC Analysis (2012)

**CHALLENGES AND IMPLICATIONS OF BAU**

Japan has scarce domestic energy resources and is highly dependent on imported energy. Although the economy’s primary energy supply is expected to decrease between 2010 and 2035, the share of its energy supply coming from fossil fuels (coal, oil and gas combined) is expected to increase throughout the outlook period (80% in 2010 and 88% in 2035). Ensuring access to secure energy resources (including equity crude oil and natural gas) remains one of the most important challenges for Japan in this period. This challenge is compounded by the forecast reduction under BAU in the contribution of nuclear energy to electricity generation—from 27% in 2010 to 6% in 2035. This decrease in nuclear use for electricity generation raises concerns for both Japan’s economic development and its environmental sustainability (in terms of CO<sub>2</sub> emissions). To pursue the best mix of energy resources will be a key focus for Japan.

## ALTERNATIVE SCENARIOS

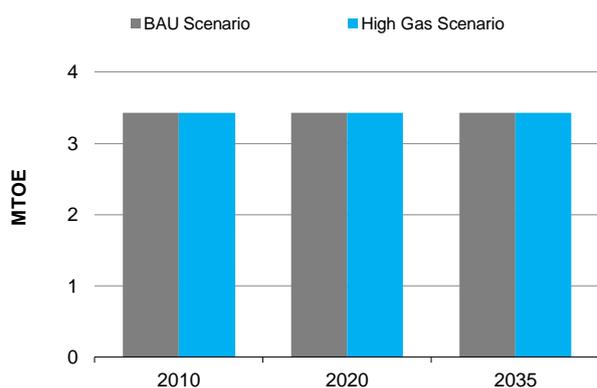
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU case prices or below, if constraints on gas production and trade could be reduced.

In the High Gas Scenario, no change was assumed in Japan’s minimal domestic production, as shown in Figure JPN8.

Figure JPN8: High Gas Scenario – Gas Production

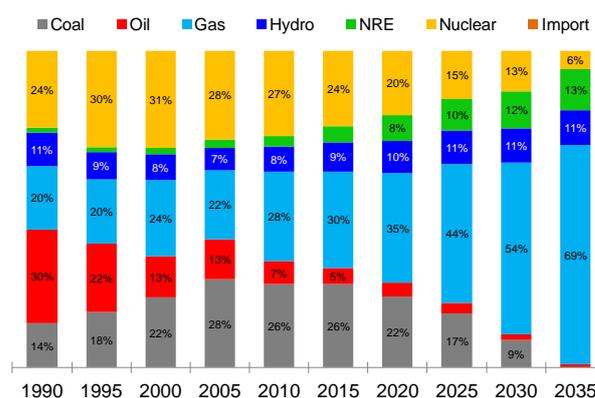


Source: APERC Analysis (2012)

However, under the High Gas Scenario, Japan would be able to import additional volumes of gas from other APEC economies at prices at or below BAU levels. Specifically, imports of gas would be up by 12% in 2020, by 25% in 2025, by 45% in 2030, and by 58% in 2035, compared to BAU. Japan would be importing an additional 49 Mtoe by 2035. It is assumed that Japan would use all of the additional gas imports for electricity generation, and that it would all be imported as LNG.

Figure JPN9 shows the High Gas Scenario Electricity Generation Mix. This graph may be compared with the BAU scenario shown in Figure JPN6. It can be seen that the gas share in 2035 has increased from 38% to 69%, while the coal share has declined from 31% to nil. So, under this scenario, Japan would be able to eliminate all of its coal-fired generation by 2035.

Figure JPN9: High Gas Scenario – Electricity Generation Mix

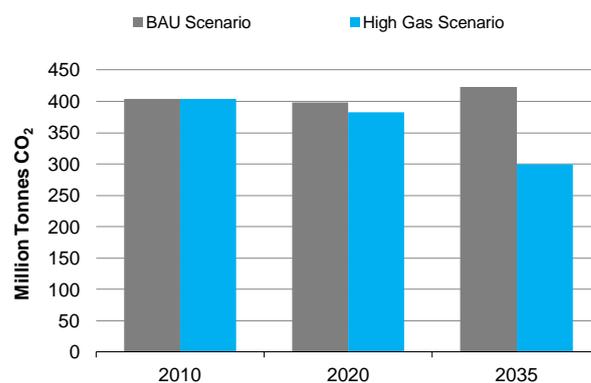


Source: APERC Analysis (2012)

Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions per unit of electricity generated that coal has, this would have the impact of reducing CO<sub>2</sub> emissions from electricity generation by 30% by 2035. Figure JPN10 shows this CO<sub>2</sub> emissions reduction.

Figure JPN10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation



Source: APERC Analysis (2012)

## ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

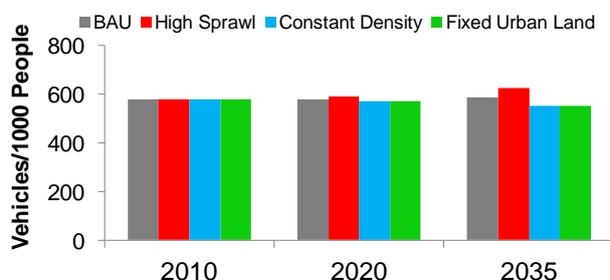
To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Since Japanese cities tend to be quite compact, and are unlikely to drop below the critical density at which transport energy demand starts to rise quickly under any scenario, the impact of better urban planning in Japan is fairly small.

Figure JPN11 shows the change in vehicle ownership under BAU and the three alternative

urban development scenarios. In the High Sprawl scenario, vehicle ownership is expected to be higher than in BAU by 7% in 2035. On the other hand, in both the Constant Density and Fixed Urban Land scenarios, vehicle ownership is expected to be smaller than in BAU by 6% in 2035.

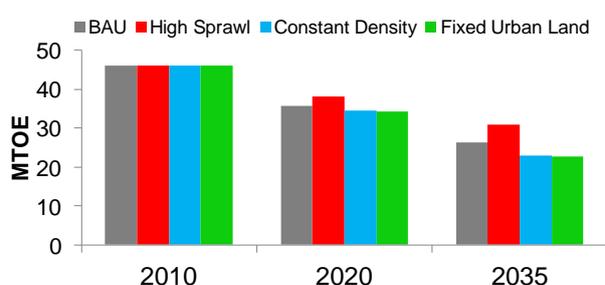
**Figure JPN11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure JPN12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of urban planning is moderate, but still significant. In the High Sprawl scenario, light vehicle oil consumption is expected to be 17% higher than BAU in 2035. On the other hand, in the Constant Density and Fixed Urban Land scenarios, light vehicle oil consumption is expected to be smaller than BAU, by 13% and 14% respectively.

**Figure JPN12: Urban Development Scenarios – Light Vehicle Oil Consumption**

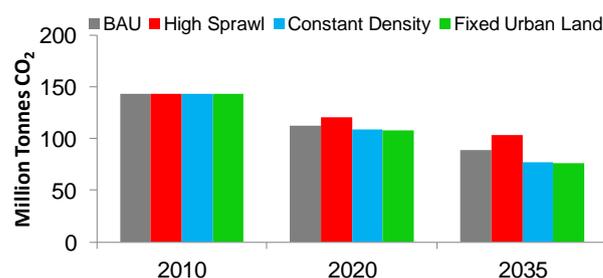


Source: APERC Analysis (2012)

Figure JPN13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

In the High Sprawl scenario, the figure for CO<sub>2</sub> emissions is 17% larger than BAU in 2035, whereas in the Constant Density and Fixed Urban Land scenarios, CO<sub>2</sub> emissions are smaller than BAU, by 13% and 14% respectively.

**Figure JPN13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



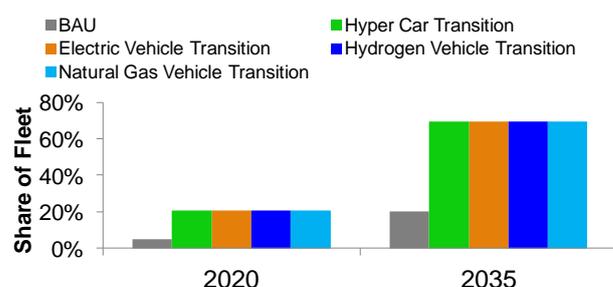
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

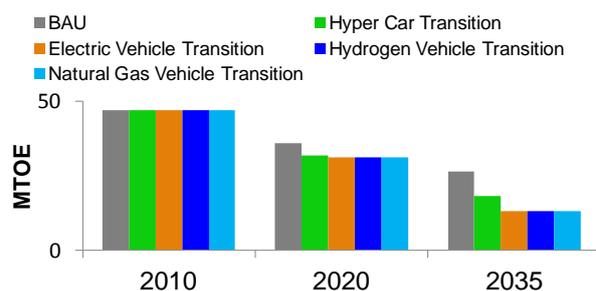
Figure JPN14 shows the evolution of the light vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035, the share of alternative vehicles in the fleet is assumed to reach 69%, compared to about 20% under BAU. The share of conventional vehicles in the fleet is thus only about 31%, compared to about 80% in the BAU scenario.

**Figure JPN14: Virtual Clean Car Race – Shares of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure JPN15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 51% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 31% by 2035, even though these highly efficient vehicles still use oil.

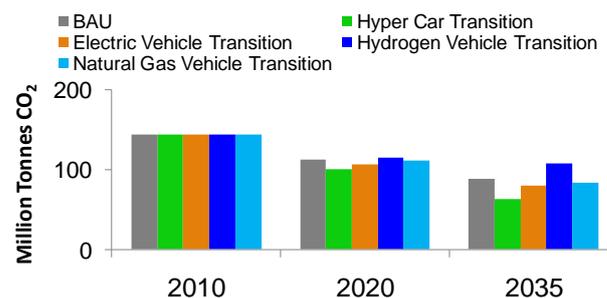
**Figure JPN15: Virtual Clean Car Race – Light Vehicle Oil Consumption**

Source: APERC Analysis (2012)

Figure JPN16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Japan, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reduction, with an emission reduction of 29% compared to BAU in 2035. The Electric Vehicle Transition scenario would also reduce emissions, but only by about 10% compared to BAU in 2035. The Electric Vehicle Transition scenario does not do as well as the Hyper Car Transition scenario in Japan because coal-fired generation is assumed to be the marginal source for much of the additional electricity required by the electric vehicles. The Natural Gas Vehicle Transition scenario would reduce emissions in 2035 by only 5%, reflecting the advances in conventional vehicle technology that are expected in Japan.

In contrast, the Hydrogen Vehicle Transition scenario would actually increase emissions by 21%, compared to BAU. This is mainly due to the way hydrogen is assumed to be produced—from steam methane reforming of gas, a process that involves significant CO<sub>2</sub> emissions.

**Figure JPN16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**

Source: APERC Analysis (2012)

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# KOREA

- Korea's primary energy supply is projected to grow at an average annual rate of 0.5%, from 229 Mtoe in 2009 to 270 Mtoe in 2035.
- Energy demand growth will slow over the outlook period as a result of Korea's population growth tailing off and of the continued structural change in the economy toward less energy-intensive industries.
- The shift in Korea's energy policy toward sustainable development is expected to facilitate the replacement of oil with renewable and nuclear energies, improvements in energy efficiency, and the optimal diversification of the economy's energy supply.

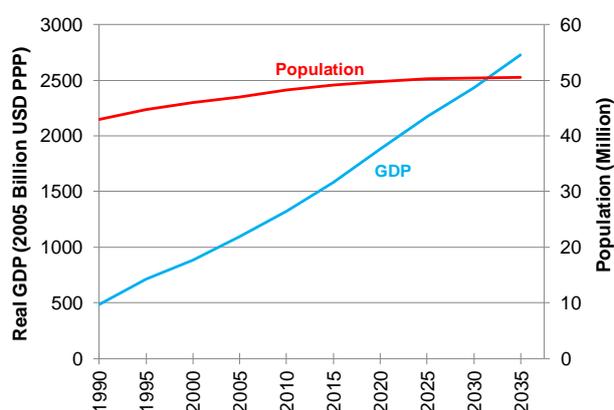
## ECONOMY

The Republic of Korea is located in North-East Asia between China and Japan. The economy's geography is largely made up of hills and mountains, with wide coastal plains in the west and the south. The climate is relatively moderate with four distinct seasons. Air conditioning is commonly necessary during the tropical hot summers and buildings need to be heated during the bitterly cold winters.

Since the 1990s, Korea has been one of Asia's fastest growing and most dynamic economies. Gross domestic product (GDP) increased at a rate of 5.1% per year from 1990 to 2009, reaching USD 1244 billion (in 2005 USD PPP) in 2009. Per capita income in 2009 was USD 25 941, more than four times higher than it was in 1990 (Global Insight, 2012).

Korea's major industries include the semiconductor, shipbuilding, steel, automobile, petrochemicals, digital electronics, machinery, parts and materials industries.

**Figure ROK1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Korea's population in 2009 was around 48 million people. The economy had an urbanization rate of 80% in 2010. Korea's population density is very high, with an average of more than 480 people per square kilometre. More than 20% of the

population lives in Seoul, Korea's capital and its largest city.

The economy's population is projected to grow at an average annual rate of 0.2% during the outlook period and to exceed 50 million people by 2020. The projection for the period 2020 to 2030 is for no population growth (KOSIS, 2012). In addition, Korea's population is ageing rapidly. After 2030, 24% of the population will be over the age of 65 years—a substantial increase from 9% in 2005 (KOSIS, 2012). The effect of these population changes on the size and composition of the labour force will have an impact on future economic growth.

The fast development of Korea's economy was based on a world class public transport system.

There are eight international and six domestic airports connecting Korean cities with almost anywhere in the world. The Incheon Airport hub consolidates Korea's position as one of the main Asian aviation transport centres.

Since 2004, Korea's KTX high speed trains have connected the economy's main cities, and almost all its towns are served by regional bus services. Six of Korea's major cities have subway systems and, in combination with extensive city bus systems, they make getting around the economy's cities easy and cost effective.

Korea has the world's largest ship building industry and it is host to a vast system of ferry and cargo services to the public. There are four major ports in Korea: Incheon, Mokpo, Pohang and Busan.

The total length of Korea's roads in 2009 was 104.9 thousand kilometres (km), 79% of which was paved. The economy had 3776 km of highways connecting its major cities (KAMA, 2012). Further development of highways is planned to overcome the congestion around the economy's big cities due to the high rates of private vehicle ownership.

In 2011, Korea was in the global top five for motor vehicle production. The economy maintained

its fifth place following China, Japan, the United States (US) and Germany. Vehicle production in 2011 hit a new record of 4.6 million units. Domestic vehicle sales were over 1.4 million units (including imported vehicles) in 2011 and the total number of registered vehicles in Korea reached 18.4 million units. Most of these were passenger cars (76.6%), 17.5% were trucks, 5.5% were buses, and 0.4% were other vehicles. Under a business-as-usual scenario, the number of registered vehicles in Korea will increase by 0.5–1% annually and by 2035 there will be around 23 million units (KAMA, 2012).

## ENERGY RESOURCES AND INFRASTRUCTURE

Korea has few indigenous energy resources. To sustain its high level of economic growth, Korea imports large quantities of energy products. The economy imported 86% of its primary energy supply in 2009 on a net basis. By the end of the outlook period in 2035, Korea will import 72% of its primary energy supply on a net basis with long-term strategy aimed to promote nuclear and NRE energy.

The economy has no oil resources. Korea's total reliance on oil imports has led to a policy of securing its oil supply by long-term contracts (about 70% of supply), spot oil transactions and overseas development.

Korea's refining industry is efficient. It had a combined crude refining capacity of about 2.8 million barrels per day in 2012.

Korea has 3 billion cubic metres of offshore natural gas reserves. This allows the production of a small amount of natural gas, satisfying only about 2% of the annual demand. Korea will continue to rely on imported LNG (liquefied natural gas) for most of its natural gas consumption. LNG imported through the Korea Gas Corporation's (KOGAS's) existing terminals in Pyongtaek, Incheon and Tongyeong will continue to be the economy's main source of natural gas used as city gas and in electricity generation. A pipeline to provide a natural gas supply from Russia is under negotiation and may be introduced after 2016.

There are 326 million tonnes of recoverable coal reserves, mainly anthracite. Existing production capacities allow the production of only 2–2.5 million tonnes of anthracite annually or about 3% of Korea's coal demand in 2010. Korea imports all its bituminous coal (KEEI, 2012).

Given these limited indigenous energy resources, Korea uses a combination of thermal (oil, natural gas and coal), nuclear and hydro electricity generation

capacities, and the facility mix has not changed much since the 1990s.

Nuclear energy has retained a high share (around 35%) of the power generation mix over the last two decades. Under a business-as-usual scenario, this is expected to increase to about 49% over the outlook period in response to climate change and energy security pressures.

New and renewable energy (NRE) sources have been widely introduced in Korea and the shares of those power sources will expand during the outlook period. Solar energy will expand for use in the residential sector, mostly for the production of hot water. Bioenergy will continue to be the largest NRE source in Korea. Bio gases will be used for electricity generation and heat production, and biodiesel will be widely used for transportation. There will be an increasing trend to use wind and geothermal energy, due to technology developments and the government's active support.

The economy-wide multi-loop electricity transmission grid has a high reliability, and Korea plans to accelerate the construction of new 765 kV large capacity transmission systems.

Korea's district heating market has expanded steadily, with about 13% of Korean households using it in 2010 (KEEI, 2012). The economy has ambitious plans for the expansion of district heating through its planning policy and tax incentives.

## ENERGY POLICIES

In the past, Korea's energy policy focused on ensuring a stable energy supply to sustain economic growth. The government is now seeking a new direction in energy policy to support sustainable development that fully considers the 3Es (energy, economy and environment).

The responsibility for energy policy development and its implementation is divided between a number of government institutions. The Ministry of Knowledge Economy (MKE) is the primary government body for energy policy.

In August 2008, faced with high energy prices and rising concerns over climate change, Korea announced a long-term strategy that will determine the direction of its energy policy until 2035. The strategy suggests the orientation of energy policy towards a vision of Low Carbon, Green Growth.

The primary goals are to improve energy intensity by 47%, and to reduce the economy's dependence on fossil fuels based on the policy of Green Growth.

The nuclear industry is viewed as a realistic alternative to reduce import dependency and to improve greenhouse gas emissions. The government will need to strengthen international cooperation in safety measures and to increase social acceptance of nuclear energy power generation if it is to push forward its plans in a post-Fukushima environment.

The Korea Government plans to expand the share of NRE in the total primary energy supply from 2.2% in 2008 to 11–12% by 2030, focusing on solar, wind and bioenergy resources. It will do this by directly investing in R&D and NRE facilities construction and by providing incentives for businesses participating in NRE development (KEEI, 2012).

Heavy dependence on the Middle East for its crude oil supply has led the economy to a policy of diversifying its oil supply during the outlook period. The state-owned Korea National Oil Corporation (KNOC) will continue to be responsible for the economy's preparedness for an oil emergency situation by operating oil stockpiling facilities and pursuing stakes in oil projects around the world.

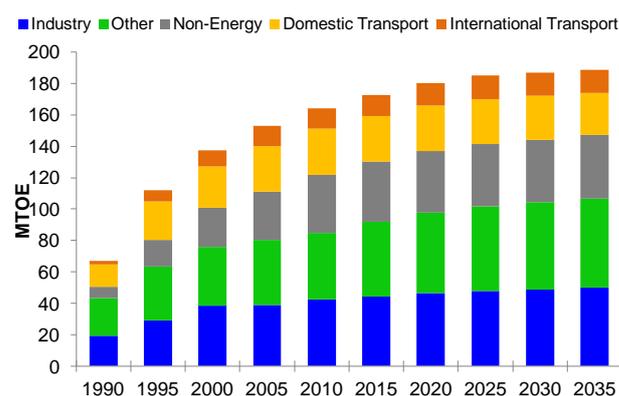
In the natural gas industry, the state-owned monopoly KOGAS will continue to be responsible for managing the import, storage, transmission and wholesale distribution of LNG. The electricity industry will continue to be dominated by the state-owned Korea Electric Power Corporation (KEPCO). It is possible there may be stages of restructuring and liberalization over the outlook period, allowing more private participation in the oil, gas and electricity industries.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Korea's total final energy demand is projected to grow at an average annual rate of 0.6% over the outlook period, led by the residential and commercial sectors.

Figure ROK2: BAU Final Energy Demand

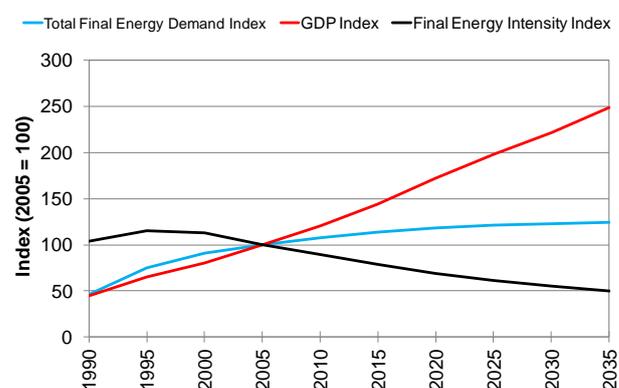


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 50% between 2005 and 2035.

Figure ROK3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.6% from 2010 to 2035. Electricity is the dominant energy source for the industry sector, although the sector's demand for natural gas is projected to increase substantially.

### Transport

The domestic transport sector's final energy demand is projected to decline at an average annual rate of 0.3% over the outlook period. This is mainly because vehicle ownership is expected to level off as economic growth slows and as population growth begins to decline after 2018.

Well-developed public transport systems (such as subway and bus services), especially in Seoul, will also help to slow the growth in transport energy demand.

The international transport sector’s final energy demand, however, will increase at an average annual rate of 0.6%, as Korea’s airports provide an increasing number of international aviation services.

**Other**

The final energy demand in the ‘other’ sector, which includes commercial and residential users, is projected to increase at an average annual rate of 1.2% over the outlook period. The increased demand is based on an expected growth in high-value-added commerce within the commercial subsector.

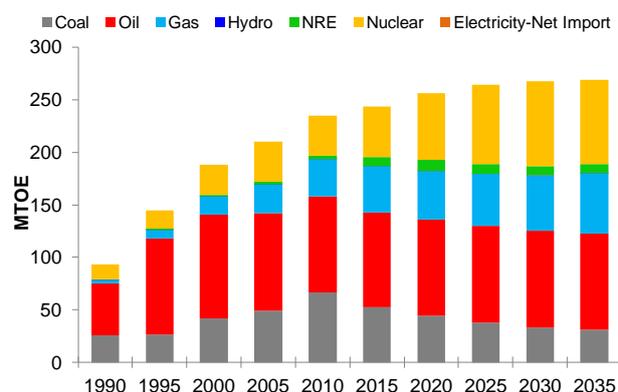
Electricity demand is expected to grow at an average annual rate of 1.6%. Demand will be driven by the spread of air conditioning and the introduction of a wider range of electrical appliances. It will be offset by the expected peaking of population growth.

Natural gas is expected to increase at an average annual rate of 0.7%. This will be driven by an increase in the demand for city gas, although that itself is expected to slow down over the outlook period compared with the growth witnessed from 1990 to 2010. That slowdown will be because the expansion of the trunk pipeline network is almost completed.

**PRIMARY ENERGY SUPPLY**

Korea’s primary energy supply is projected to grow at an average annual rate of 0.5% over the outlook period. This growth rate is much lower than the growth rate of 5.6% between 1990 and 2005. The projected lower growth rate will be due to energy efficiency improvements and limited population growth.

*Figure ROK4: BAU Primary Energy Supply*



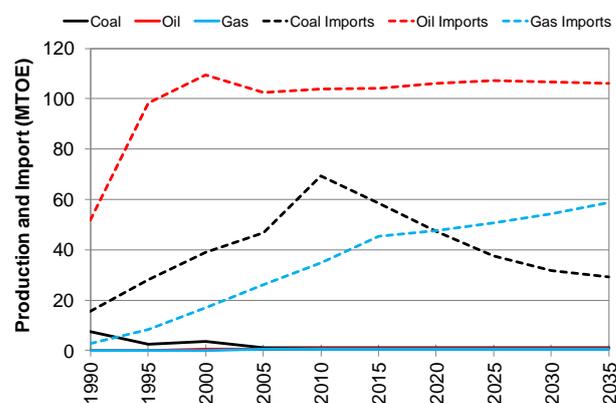
Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Oil is expected to remain the dominant energy source through to 2035 but its share will stay constant at around 36%. About half of the oil demand will be for non-energy use by 2035. At the

same time, natural gas is projected to increase its share from 14% in 2010 to 23% by 2035; it will grow at an average annual rate of 2.2%. Renewable energy is estimated to grow at a high average annual rate of 5% from 2010 to 2020, and at 2–3% from 2020 onwards, as a result of efforts to diversify energy resources to improve the economy’s energy security. However, its share will continue to be small.

Korea will continue to import large quantities of energy products. By 2035, oil imports will be 105 million tonnes of oil equivalent (Mtoe), which is similar to the 2010 level, and natural gas 60 Mtoe. Securing a stable supply of oil and natural gas will be the main energy agenda for Korea over the outlook period. Coal imports will decline, mainly due to the ecological restriction on the use of coal for power generation.

*Figure ROK5: BAU Energy Production and Net Imports*



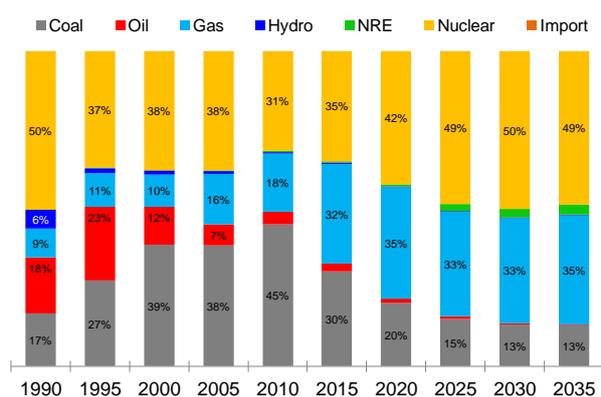
Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

**ELECTRICITY**

Korea’s electricity demand is projected to grow at an average annual rate of 1.1% over the outlook period. This is much lower than the 9.3% annual growth recorded between 1990 and 2005. More than half of this demand growth is expected to come from the ‘other’ sector, followed by the industry sector.

The electricity generation mix is expected to change slightly if the government’s 2008 long-term strategy is followed. The nuclear share will expand to 49% by 2035 from 31% in 2010, while oil will account for less than 1% (a substantial decrease from its 7% share in 2005). At the same time, natural gas is projected to increase from 18% in 2010 to 35% of the mix in 2035. Renewable energy is expected to grow the fastest, at an average annual rate of 8%, although its share will be less than 5% in 2035. There are no plans for the further development of hydro power in Korea due to a lack of suitable locations.

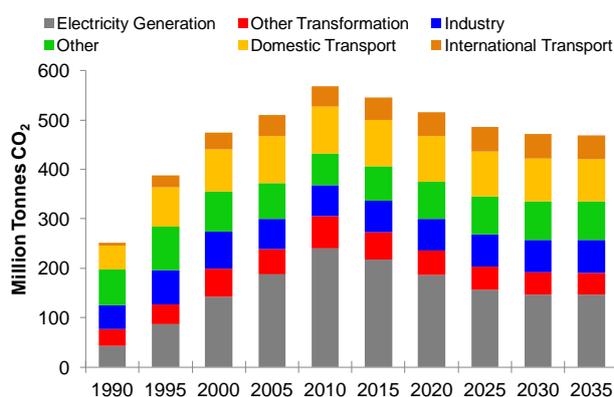
Figure ROK6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

## CO<sub>2</sub> EMISSIONS

Korea's CO<sub>2</sub> emissions are estimated to decline by 18% over the outlook period, from 570 million tonnes of CO<sub>2</sub> in 2010 to 470 million tonnes of CO<sub>2</sub> by 2035. This is because natural gas and nuclear energy are expected to increase their shares in the electricity generation mix by 2035.

Figure ROK7: BAU CO<sub>2</sub> Emissions by Sector

Source: APERC Analysis (2012)

From the decomposition analysis shown in Table ROK1, it can be seen that economic growth underlies Korea's CO<sub>2</sub> emissions increase through the outlook period. This will be offset by a change in energy intensity (energy efficiency) and carbon intensity (fuel switching).

Table ROK1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-2.6%	10.3%	0.6%	0.5%	-1.4%
Change in Energy Intensity of GDP	0.0%	-2.0%	-2.2%	-2.2%	-2.3%
Change in GDP	5.5%	3.8%	3.2%	3.1%	2.9%
Total Change	2.8%	12.3%	1.6%	1.3%	-0.8%

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

Korea's energy policy shift towards sustainable development is expected to be maintained through to 2035. However, the achievement of a cleaner energy supply for the economy is less certain.

The expansion of nuclear energy power generation may not progress as planned, due to public opposition. Even though there is a good understanding of the importance of nuclear energy by the Korean public, the acceptance of a new power plant at a local level can still be a significant barrier. Delays in nuclear energy power plant construction may result in other energy sources being retained for power generation.

Furthermore, the achievement of the government's target for increasing renewable energy's contribution to the primary energy supply (11% after 2030) is also uncertain. Strong and constant government support for the efforts to increase renewable energy use will be essential if the target is to be achieved.

Energy security will remain a critical issue for any economy such as Korea that relies on imports for most of its energy resources. Even with an expanded share of the primary energy supply coming from nuclear and renewable sources, the projected continuing emphasis on coal for electricity generation, oil for transport use and LNG in the residential sector will leave Korea importing the majority of its energy resources. It is therefore assumed Korea will experience significant challenges in its efforts to better secure its energy supply.

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies, including the Republic of Korea.

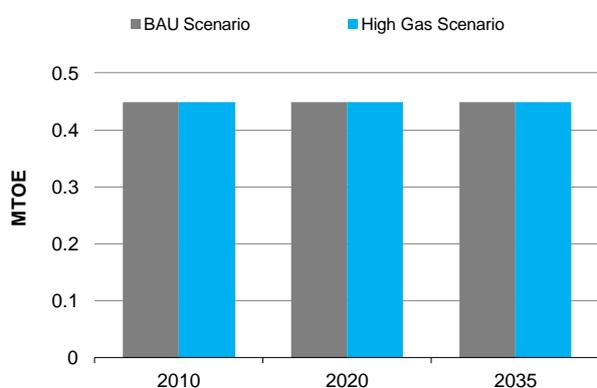
### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Korea assumed the production levels would be kept constant at 0.45 Mtoe, as shown in Figure ROK8, through to 2035. The High Gas Scenario assumption primarily

removes the import restrictions, including for the possible pipeline supply from the Russian Federation.

**Figure ROK8: High Gas Scenario – Gas Production**

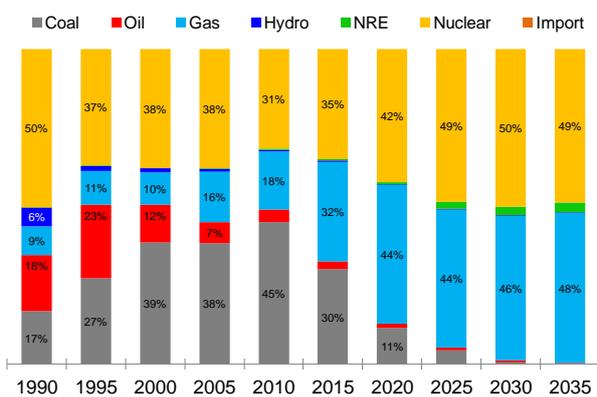


Source: APERC Analysis (2012)

Additional gas consumption in Korea in the High Gas Scenario will depend on the gas market situation in the APEC region. In a high gas availability situation, additional gas will be used to totally replace coal in electricity generation by 2035.

Figure ROK9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU case graph shown in Figure ROK6. It can be seen that the gas share has increased by 13% by 2035, while the coal share has declined from 13% to zero.

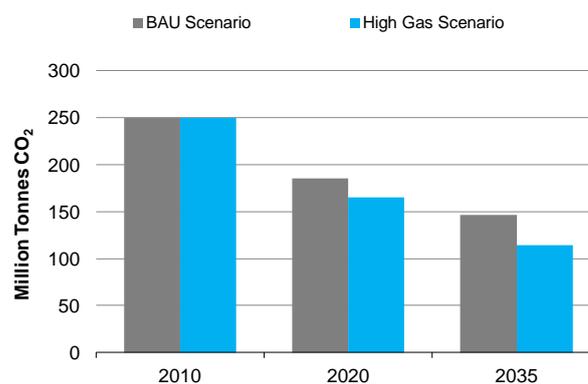
**Figure ROK9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by 21% by 2035. Figure ROK10 shows this CO<sub>2</sub> emissions reduction.

**Figure ROK10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



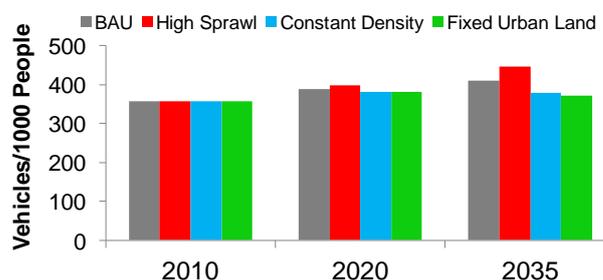
Source: APERC Analysis (2012)

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure ROK11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level of vehicle saturation on long-term vehicle ownership. Since vehicle ownership is near saturation in Korea, the impact of a change in urban planning on vehicle ownership for large Korean cities like Seoul, Busan and Daegu is significant.

**Figure ROK11: Urban Development Scenarios – Vehicle Ownership**

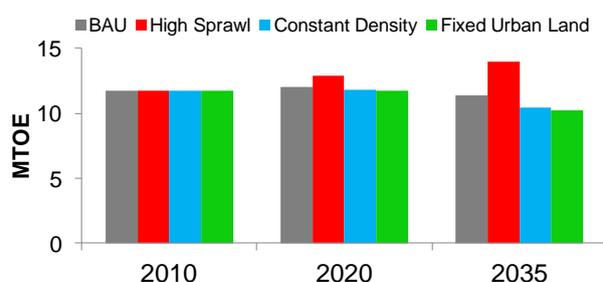


Source: APERC Analysis (2012)

Figure ROK12 shows the change in light vehicle fleet oil consumption under BAU and the three alternative urban development scenarios. The impact on oil consumption from the change in the size of the light vehicle fleet is compounded by the change in the distance travelled per vehicle. In compact cities, modelled by the Fixed Urban Land scenario,

travel distances per vehicle are typically lower than in sprawling cities modelled by the High Sprawl scenario. As a result, light vehicle oil consumption would be 23% higher in the High Sprawl scenario compared to BAU in 2035, and about 9% and 10% lower in the Constant Density and Fixed Urban Land scenarios respectively.

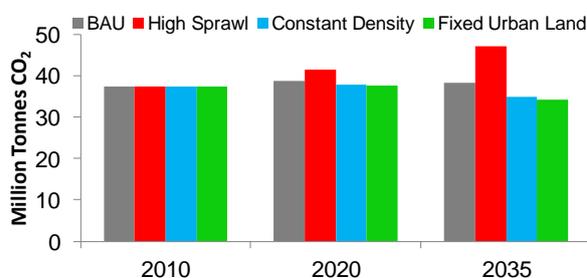
**Figure ROK12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure ROK13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure ROK13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

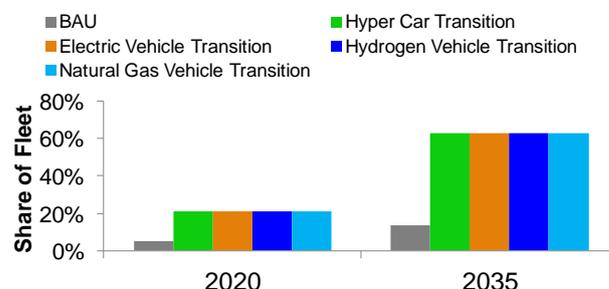
### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure ROK14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60%

compared to about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 90% in the BAU scenario.

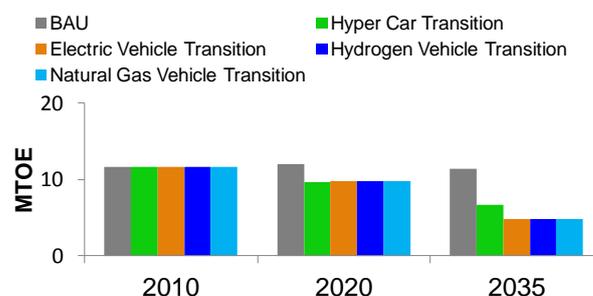
**Figure ROK14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure ROK15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 53% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—30% by 2035—even though these highly-efficient vehicles still use oil.

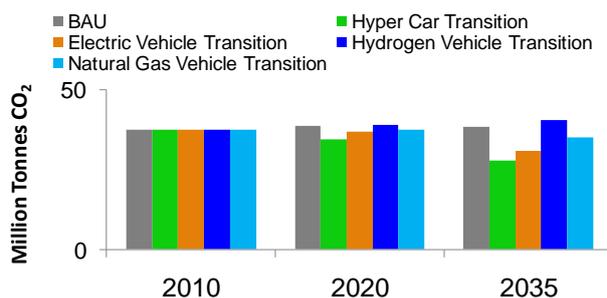
**Figure ROK15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure ROK16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure ROK16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Korea, the Hyper Car Transition scenario is the winner in terms of CO<sub>2</sub> emissions savings, with an emissions reduction of about 28% compared to BAU in 2035. Reflecting Korea's relatively low-carbon electricity generation, the Electric Vehicle Transition scenario comes in second, with an emissions reduction of 20% compared to BAU in 2035. Reflecting the lower carbon-intensity of natural gas compared to oil, the Natural Gas Vehicle Transition scenario achieves an emissions reduction of about 8% compared to BAU in 2035. Reflecting the inefficiency of producing hydrogen vehicle fuel from natural gas, then converting the hydrogen to electricity in the vehicle, the Hydrogen Vehicle Transition scenario would actually increase emissions by 6% compared to BAU in 2035.

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# MALAYSIA

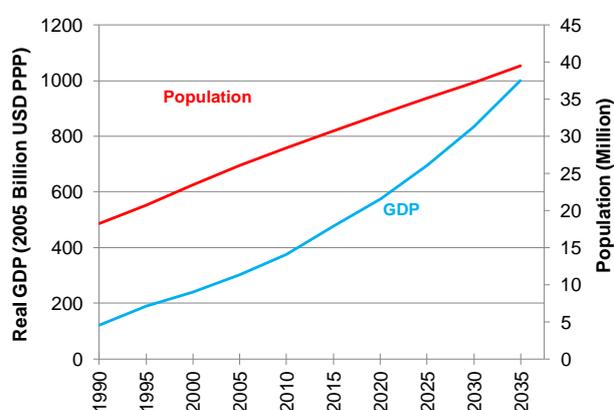
- Malaysia's primary energy supply is projected to grow at 1.7% a year, to reach 103 Mtoe in 2035. The growth is driven mainly by demand for gas in the electricity generation sector and demand for oil in the transport sector.
- The oil and gas sectors have long been significant contributors to Malaysia's GDP and energy security, but this is likely to change due to rising domestic demand and maturing reserves. To meet this challenge, Malaysia will sustain production by rejuvenating existing fields and intensifying exploration activities while enhancing downstream growth and leveraging on its strategic location to become a regional hub for oilfield services.
- Electricity demand is expected to increase significantly from 96.3 TWb in 2009 to 206 TWb in 2035. To better manage this increasing demand, Malaysia aims to encourage efficient use of energy through initiatives like the Malaysia Green Labeling Program and Green Building Index, and to diversify its energy sources by building up solar capacity and tapping its vast hydroelectricity potential.

## ECONOMY

Malaysia is located in South-East Asia. Its territory covers an area of 330 803 square kilometres, spread across the southern part of the Malay Peninsula and the Sabah and Sarawak states on the island of Borneo. Malaysia's neighbours include Indonesia, Singapore, Thailand and Brunei Darussalam. Malaysia currently shares electricity interconnections with both Thailand and Singapore. Gas pipelines link Malaysia to Thailand, Singapore and Indonesia.

In 2009, Malaysia's total population was estimated to be about 28.3 million, with over 70% living in urban areas (DOS, 2011). Since its interior terrain is mostly forest-covered mountains, the Malaysian population is largely concentrated on the coastal plains. Malaysia's highest population densities are found in the peninsula cities of Kuala Lumpur, Penang and Putrajaya (DOS, 2011). The total population is projected to grow at an average annual rate of 1.3% over the outlook period, reaching just below 40 million by 2035.

**Figure MAS1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Malaysia's GDP per capita in 2009 was estimated to be about USD 12 600 (in 2005 USD PPP), the third highest among the ASEAN economies. Based on current trends, Malaysia's annual GDP growth is predicted to be 4% for the next 25 years. Poverty has mostly been eradicated, and there is generally good access to water, electricity and telecommunications facilities.

Malaysia is an upper-middle-income developing economy with aspirations to achieve developed status by the year 2020. The Vision 2020 objective was first announced in 1991; since then several initiatives and programs have been put into place to drive economic growth. The latest, the Economic Transformation Programme (ETP), was launched in 2010 and is the most comprehensive initiative yet, incorporating active participation from the private sector and business community. Under the ETP, 131 Entry Point Projects (EPPs) were identified and categorized under 12 National Key Areas (NKEA) to provide focused economic growth. The 131 EPPs are high-impact projects, matched with specific ideas and actions, and are prioritized in government planning and fund allocation. By the end of 2011, 83% of the EPPs had either begun work or were currently in operation (PEMANDU, 2012). These accelerated EPPs are expected to stimulate economic growth, and this will be matched by corresponding growth in energy demand.

Manufacturing is a major contributor to the Malaysian economy, particularly the electrical and electronics, chemical products, and petroleum products manufacturing industries. Natural gas and electricity are the main energy sources used, while coal is used mostly by the cement, and iron and steel manufacturing industries.

Mining and agriculture are two other important economic activities; in 2009, each sector contributed

7.7% of the Malaysian GDP (MOF, 2011). Tin, oil and gas are the major natural resources of export significance in the mining sector. Other minerals mined in Malaysia include iron ore, bauxite, coal, ilmenite and gold. Overall, mining will continue to play a small but vital role in the economy.

The agricultural sector, which includes fisheries and forestry, has been identified as one of the NKEAs under the ETP and is currently undergoing rapid modernization and commercialization. As a result, the sector is expected to experience consistent economic growth in coming years. Some of these measures are already paying off: Malaysia is now one of the leading producers of palm oil worldwide and through concerted research initiatives, new applications of palm oil in biofuel production and biomass power generation have been successfully implemented.

In terms of passenger and freight volumes, road transport is the leading transportation mode in Malaysia (Ong et al., 2012). Malaysia has extensive road networks, totalling 157 167 km at the end of 2011, of which 81% are paved (EPU, 2012, p. 30). There are a total of 28 high-speed divided highways in the economy with a total length of 2137 km (LLM, 2012).

In 2009, there were about 19 million registered vehicles in Malaysia, and this is increasing at an average annual growth rate of 6.4% (RTD, 2010). Malaysian manufactured cars from Perodua and Proton currently dominate the economy's automobile market, although decreasing import taxes mean imported cars from Japan and Europe are gaining a greater share of the market each year. There is a mixture of new and rebuilt imported cars available in Malaysia, based on the economy's healthy rebuilt vehicle industry—there are eight rebuilt car manufacturers and nine rebuilt motorcycle manufacturers. Given the ease of obtaining car loans and subsidized fuel prices, car ownership is high among the population. According to the Malaysian Automotive Industry, based on historical trends it is unlikely that car ownership will reach saturation level in the near future, and car sales are expected to continue to grow at a moderate rate (MAI, 2011).

Rail transport, monorail and light rail transit systems also play significant roles in the land transport system, especially in Kuala Lumpur, Malaysia's capital city. Malaysia also has excellent marine port and airport infrastructure in key locations, which allows Malaysia to take advantage of its strategic position in the middle of the Trans-Asian route. In its Tenth Malaysian Plan, which covers 2011–2015, Malaysia has budgeted about

MYR 13 billion (about USD 4.3 billion) to upgrade and enhance transportation access and connectivity (EPU, 2011). Some of the planned projects are to build road and rail links to major ports and airports, build electrified double-track rail lines, deepen port channels, upgrade marine ports and expand airport capacity.

Malaysia's equatorial climate has year-round average temperatures of 20–35°C and relative humidity of 80–90%; the timing of the rainy season on the peninsula coast varies. The tropical climate requires year-round space cooling in Malaysian buildings. On average, space cooling accounts for nearly 40% of the total building energy requirement. Malaysia is relatively safe from extreme natural disasters like earthquakes and hurricanes, although mild flooding does occur in certain regions, causing damage to properties but generally no loss of life.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Malaysia is blessed with a variety of primary energy resources, including oil, natural gas, coal and renewable energy. According to the Malaysian Economic Planning Unit, as of 1 January 2011, there is an estimated 2.5 trillion cubic metres (89.9 trillion cubic feet) of natural gas and 5.9 billion barrels of oil reserves available, that will last 39 and 25 years respectively (EPU, 2011). The National Depletion Policy of 1980 aims to safeguard depleting reserves by restricting the production of hydrocarbons to 3% of 'oil initially in place'. This effectively limits the production of crude oil to 650 000 barrels per day and natural gas in Peninsular Malaysia to 2000 million standard cubic feet (56.6 million cubic metres) per day (KeTTHa, 2009). The economy also has about 1.9 billion tonnes of coal resources that are largely underexploited (Tse, 2011).

The majority of Malaysia's oil production comes from offshore fields in the Malay basin in the west, as well as the Sabah and Sarawak basins in the east. Malaysia's oil quality is generally high, but production has been declining in the past decade. To extend the reserves' lifetime, oil exploration activities are being expanded into deepwater—an activity which is significantly more challenging, both economically and technically. The Kikeh project was the first successfully developed deepwater oilfield in Malaysia, with two more deepwater fields under development in Gumusut/Kakap and Malikai (Rasheed Khan and Murzali, 2008).

There are five oil refineries in Malaysia with a combined capacity of 492 000 barrels per day—used for both domestic consumption and export (EC,

2012, p. 31). A sixth refinery will be added by 2014 under the Refinery and Petrochemical Integrated Development (RAPID) project in Pengerang, Johor. The refinery will have a capacity of 300 000 barrels per day and will supply feedstock for RAPID's petrochemical complex as well as produce gasoline and diesel that meet European specifications (Petronas, 2012b).

Like its oil reserves, the economy's natural gas reserves lie offshore of Peninsular Malaysia's east coast, Sabah and Sarawak. The three most active areas are the Malaysia–Thailand Joint Development Area (JDA), the SK309/SK311 area in offshore Sarawak, and Bintang area near Terengganu.

Malaysia has two gas pipeline networks. The Peninsular Gas Utilisation (PGU) network now includes over 2500 km of pipelines linking most cities in Peninsular Malaysia and it has cross-border interconnections to Singapore and Songkhla, Thailand. The PGU pipeline system incorporates six gas-processing plants with a combined capacity of 56.6 million cubic metres (2060 million standard cubic feet) per day, producing methane, ethane, butane and condensate (Gas Malaysia, 2012). The system receives gas from offshore Peninsular Malaysia fields as well as imported gas from JDA, West Natuna and PM3 CAA fields. About half the PGU system gas is consumed by the power sector while the rest goes to non-power industries or is exported to Singapore (Maybank, 2012).

The second gas pipeline linking the states of Sabah and Sarawak is under construction and expected to be completed by 2013. The Sabah–Sarawak Gas Pipeline (SSGP) will be approximately 521 km in length, and will deliver natural gas from Kimanis in Sabah to an LNG facility in Bintulu, Sarawak (OBG, 2012).

The economy operates extensive LNG export facilities and produces 13% of world LNG exports. As of 2010, Japan remained the largest importer of Malaysia's LNG, followed by Korea and Chinese Taipei (MLNG, 2011). To meet the anticipated shortfall of gas in the Malay Peninsula, Malaysia constructed its first LNG Regasification Terminal (RGT) in Malacca, which was completed in mid-2012. Once fully operational, the terminal will have the capacity to process and store up to 3.8 million tonnes per annum of LNG. A second RGT is being planned for the Pengerang Integrated Petroleum Complex (PIPC) in Johor (OBG, 2012) and a third RGT in Lahad Datu, Sabah.

Bituminous and sub-bituminous coals make up the bulk of coal reserves in Malaysia. Although the coal resource in Malaysia is substantial, domestic coal

production has not been aggressively pursued because most of these coal deposits are far inland, where infrastructure is lacking and the extraction cost is high. Some locations, like the Maliau Basin in Sabah, have been designated as protected areas. Currently, coal mining is only conducted in Sarawak—production comes from the areas of Bintulu, Merit-Pila, Silantek and Tutoh. In Peninsular Malaysia, coal is used primarily for power generation, by the iron and steel industry, and by cement manufacturers. At present, coal is imported from Australia, Indonesia, South Africa and Viet Nam (Tse, 2011).

Renewable resources, especially hydropower and biomass, are in abundance in the economy. Malaysia's hydropower potential is assessed at 29 000 MW, mostly located in East Malaysia. In 2008, it was announced that several large hydroelectric projects will be developed under the Sarawak Corridor of Renewable Energy (SCORE); this will take over 20 years to develop and will generate a total of 20 000 MW when completed.

Small-scale generation from mini-hydro, biomass, solar and wind are already in place, totalling 773.6 MW. Of this figure, 15.3% is currently grid-connected while the rest is for self-generation in the industry sector. Over 90% is based on biomass power generation (EC, 2012). In 2011, the Malaysian Parliament approved a sophisticated system of feed-in tariffs that came into effect on 1 December 2011. This is expected to accelerate renewable energy development in the economy.

## ENERGY POLICIES

Malaysia's National Energy Policy was first formulated in 1979 by the Economic Planning Unit under the Prime Minister's Department. The policy consists of three principal energy objectives:

1. *The Supply Objective.* To ensure the provision of adequate, secure and cost-effective supply of energy.
2. *The Utilization Objective.* To promote efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption.
3. *The Environmental Objective.* To minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment.

These three principle objectives are instrumental in the development of Malaysia's energy sector. Subsequent policies are designed to support these objectives and their implementation.

The National Depletion Policy was formulated in 1980 to prolong and preserve the economy's oil and gas resources by setting a limit on the annual production of oil and natural gas. A year later, the economy introduced the Four-Fuel Diversification Policy, with the aim of diversifying the energy mix used in electricity generation. The initial focus of this policy was to reduce the economy's dependence on oil as the principal energy source, and it aimed for the optimization of the energy mix of oil, gas, hydro and coal used in generation of electricity. As a result, oil's domination of the electricity generation energy mix has been significantly reduced and replaced with gas and coal. In 2001, the Five-Fuel Diversification Policy was introduced to incorporate renewable energy as the fifth fuel after oil, gas, coal and hydro.

To diversify fuel use in non-power sectors, particularly the transportation sector, the National Biofuel Policy was introduced in 2006. The policy promotes the production of biofuel by the blending of processed palm oil (5%) with petroleum diesel (95%), it promotes biofuel consumption by establishing biodiesel pumps at selected stations, it ensures biodiesel quality by establishing an industry standard, and it encourages production by encouraging the establishment of biodiesel plants (MPICM, 2006).

At the 2009 Climate Change Summit in Copenhagen, Malaysia's Prime Minister pledged to "voluntarily reduce CO<sub>2</sub> emission intensity of GDP up to 40% by 2020 as compared to 2005 levels, conditional on financial and technological assistance from developed countries". Subsequently, the National Green Technology Policy was formulated, based on four pillars:

1. To attain energy independence and promote efficient utilization
2. To conserve and minimize environmental impacts
3. To enhance economic development through the use of green technology
4. To improve quality of life for all.

Four focus sectors were chosen—energy, buildings, waste and waste management, and transportation. As at mid 2012, several key initiatives have been introduced under the National Green Technology Policy. Government initiatives include the restructuring of the Malaysian Green Technology Corporation, the organization of the annual International Greentech and Eco Products Exhibition and Conference Malaysia (IGEM), the development of Putrajaya and Cyberjaya as pioneer townships in Green Technology, and establishing the Green Technology Fund Scheme (GFTS) which

provides MYR 1.5 billion (USD 490 million) for green technology schemes.

The Malaysia Green Labelling Program (MGLP) has also been introduced—this includes the National Eco Labelling Program to certify eco-friendly domestically manufactured products, and the Energy Star Rating certification for energy-efficient home appliances. To promote green technology in the building sector, the Green Building Index (GBI) has been developed. To obtain a GBI certificate, the developer must ensure that the building meets six criteria: energy efficiency, indoor environmental quality, sustainable site planning and management, use of sustainable materials and resources, water efficiency, and innovation.

The National Renewable Energy Policy and Action Plan came into being in 2010. Its aim is to spur utilization of indigenous renewable energy resources to contribute towards Malaysia's electricity supply security and sustainable socio-economic development. Under this policy, two crucial Acts were established: the Renewable Energy Act 2011 and the Sustainable Energy Development Authority Act 2011, which together set up the framework for the new feed-in tariff mechanism.

The current five-year Malaysian plan, the Tenth Malaysian Plan 2011–2015, and its New Energy Policy aim to address several key issues to ensure economic efficiency and security of supply while still meeting social and environmental objectives.

One crucial issue is rationalizing fuel subsidies. Subsidies represent a substantial financial burden to the Malaysian Government. For instance, in 2009, fuel subsidies alone amounted to MYR 6.2 billion (USD 2 billion), which is almost 4% of government operating expenditure (MOF, 2011). Realizing that subsidies are unsustainable and may lead to sub-optimal resource allocation, as well as negatively impact market efficiency and impede long-term growth potential, the Malaysian Government has started taking steps to restructure subsidy allocations. Under the New Energy Policy, the price of gas to the power sector will be gradually raised by MYR 3 (USD 0.98) per million British thermal units every six months, eventually reaching the market price by 2016. At the same time, subsidy amounts will be itemized in consumer utility bills to increase awareness and encourage efficient energy use. Vehicle fuel subsidies remain unchanged.

The New Energy Policy addresses the energy security issue by developing alternative resources, with emphasis on renewable and clean carbon technology for the power generation sector, and biofuels for the transportation sector. Existing

measures that encourage efficient use of energy, such as the Malaysia Green Labelling Program (MGLP) and Green Building Index (GBI) initiatives, will be extended and further enhanced under the New Energy Policy.

In Malaysia, the government-owned company Petronas holds exclusive ownership rights to all oil and gas exploration and production projects, and all foreign and private companies must operate through production sharing contracts (PSC). In terms of electricity production, the industry is dominated by three integrated utilities: Tenaga Nasional Berhad (TNB) serving Peninsular Malaysia, Sabah Electricity Berhad (SESB) in Sabah state and Sarawak Energy Berhad (SEB) in Sarawak state. TNB is publicly listed while SESB and SEB are privately owned, with the government owning some shares in each utility. The three utilities are complemented by various independent power producers (IPPs), dedicated power producers and co-generators. Under the New Energy Policy, both the gas and electricity sectors are slated for restructuring to raise productivity and improve business efficiency.

At the same time, under the Economic Transformation Programme (ETP), Malaysia has outlined 12 Entry Point Projects (EPPs) for the oil, gas and energy industries. The 12 EPPs are categorized under four main thrusts:

1. *Sustaining oil and gas production.* This involves extending the lifecycle of existing resources by optimizing exploration, development and production activities.
2. *Enhancing downstream growth.* The two EPPs under this thrust involve building a regional oil storage and trading hub, and unlocking gas demand in Peninsular Malaysia by providing better access to gas (through LNG imports and PGU infrastructure), thus encouraging industrial users to switch from diesel to competitively priced natural gas.
3. *Making Malaysia the number one Asian hub for oilfield services.* This thrust leverages on the economy's strategic location, to attract global operations and to build strategic partnerships and joint ventures for developing engineering, procurement and installation capabilities.
4. *Building a sustainable energy platform for growth.* The four EPPs under this thrust are designed to ensure energy security by improving energy efficiency and diversifying energy resources. This includes building up solar power capacity and tapping into Malaysia's hydroelectricity potential.

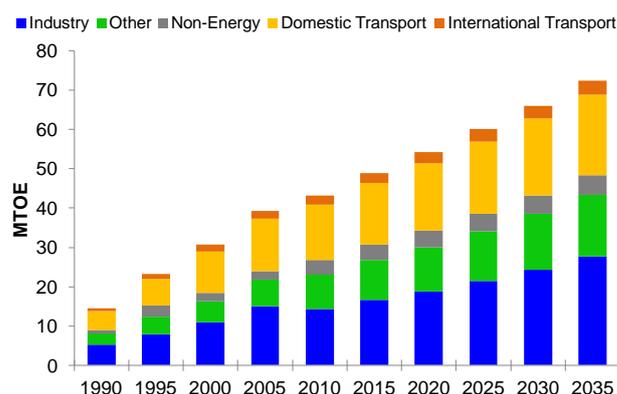
Deploying nuclear energy for electricity generation was one of the EPPs introduced under ETP, but after the Fukushima Nuclear Accident in May 2011, there has been growing public concern regarding the safety and increasing cost of nuclear power development. As of October 2012, the government has yet to decide on the construction of a nuclear power plant or its proposed location (The Star, 2012).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

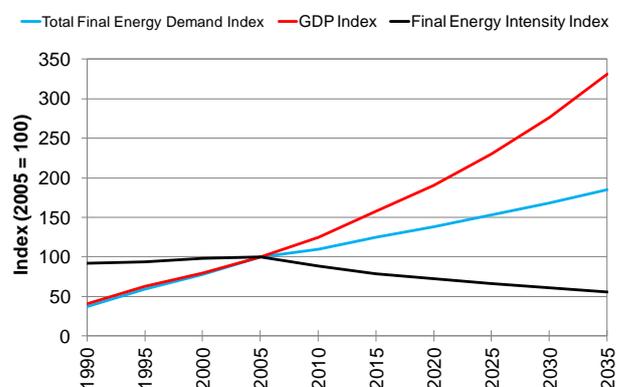
Malaysia's final energy demand (excluding the international transport sector) is projected to grow at an average annual rate of 2.1%, reaching 69 Mtoe by 2035 under business-as-usual (BAU) assumptions. The industry sector accounts for the largest portion with a share of 38% by 2035, followed by the domestic transport sector at 28%. Malaysia's final energy intensity is projected to decline by 44% between 2005 and 2035.

Figure MAS2: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Figure MAS3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

## Industry

By 2035, natural gas will account for the largest share of the final industry demand (33%), followed by electricity and oil, at 28% each. The final energy demand for the industrial sector is expected to nearly double over the outlook period, reaching 28 Mtoe in 2035. The energy intensity for the industrial sector, calculated as industrial demand divided by current GDP, is expected to reduce by 28% within the same time period. This reflects the sector's shift towards a structure that is less energy intensive as well as improvements in technical energy efficiency.

## Transport

The transport sector energy demand is projected to increase in the outlook period by an average annual rate of 1.5% for domestic transport and 1.8% for international transport, reaching a total of 24 Mtoe in 2035. Petroleum products are expected to remain the dominant transport energy source, but other energy resources, especially natural gas and biofuels, are expected to contribute an increasing share over the outlook period, together accounting for about 3% of the total transport final energy demand in 2035. This would be in line with existing government incentives to encourage utilization of natural gas and biofuel in light vehicles. Currently, the fuelling stations for non-petroleum products are very limited and concentrated mostly within the Klang Valley. The contribution from natural gas would likely increase dramatically if the fuelling stations were more widespread across the economy.

## Other

The final energy demand for the 'other' sector, which includes commercial, residential, and agriculture sub-sectors, is projected to grow at an average annual rate of 2.4%, reaching 16 Mtoe in 2035. Electricity constitutes the largest portion, with a share of about 62% (10 Mtoe) in 2035. This will be heavily driven by the need for space cooling. Generally, most urban dwellings are currently equipped with at least basic electrical home appliances such as televisions and refrigerators. Air conditioning is less common outside cities and townships as fans are deemed sufficient to cope with the humid weather. This moderate growth trend will likely continue throughout the outlook period unless there is a drastic change in climate.

## PRIMARY ENERGY SUPPLY

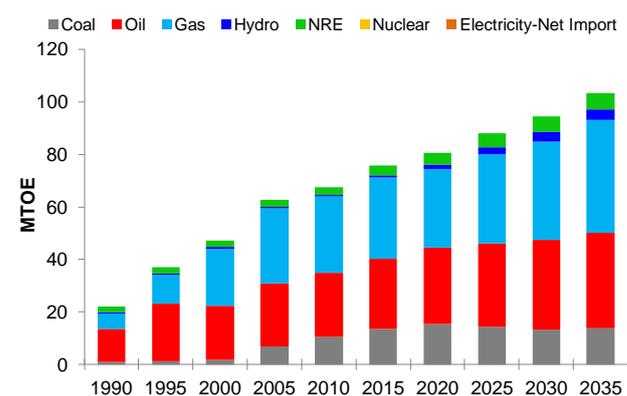
This outlook projects that Malaysia's primary energy supply will increase significantly from 66 Mtoe in 2009 to over 100 Mtoe in 2035, at an annual average rate of 1.7%. Fossil fuels will account for most of the primary energy supply in 2035, with oil at 35% and gas 42%.

In the medium term, it is expected that the economy will be able to sustain its oil production through the government's initiative under ETP to rejuvenate existing oilfields and explore new fields like the Kikeh deepwater field. However, given the economy's maturing oil reserves and the technical and economic issues involved in developing deepwater oilfields, it is likely that production will begin to decline and Malaysia will be a net oil importer by 2025.

Intensified exploration of natural gas fields under ETP has had some success: several new fields have been discovered including Block H off the coast of Sabah (MOC, 2012) and Block SK316 off the coast of Sarawak (Petronas, 2012a). This will lead to increased gas production in the mid-term, and consistent production up to 2030, after which production may begin to decline.

Coal production will remain minimal throughout the outlook period. Coal is mostly consumed by the electricity generation sector, and coal imports are expected to fluctuate according to the addition and retirement of coal power generation capacity throughout the period.

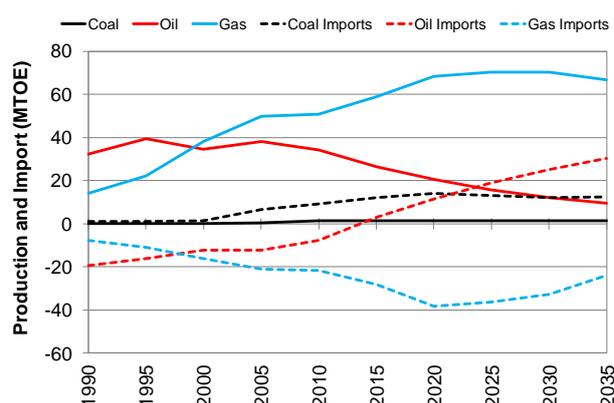
Figure MAS4: BAU Primary Energy Supply



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure MAS5: BAU Energy Production and Net Imports



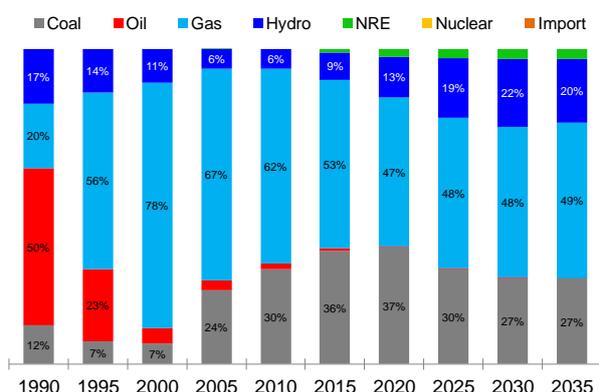
Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**ELECTRICITY**

Electricity generation in Malaysia is projected to grow over the outlook period at an average annual rate of 2.8%, doubling from 105.1 TWh in 2009 to 217 TWh in 2035. A key goal for the economy is to create a more balanced generation mix. In order to achieve this, natural gas dependence will be reduced from 62% in 2010 to 49% in 2035. The reduced natural gas share will be taken up by hydro and new renewable energy (NRE).

Hydroelectric generation is projected to grow strongly during the outlook period, based on the development of large hydro projects in Sarawak under the SCORE initiative. NRE, mostly from biomass and solar sources, will also continue to grow from its currently negligible contribution to over 6 TWh in 2035 with the implementation of the feed-in tariff mechanisms.

Figure MAS6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

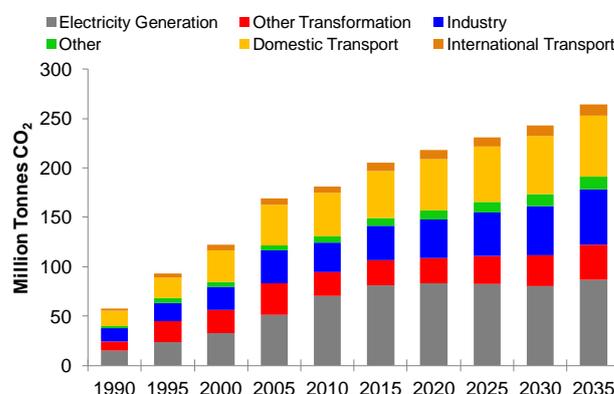
**CO<sub>2</sub> EMISSIONS**

Total CO<sub>2</sub> emissions from fuel combustion are projected to reach 264 million tonnes CO<sub>2</sub> in 2035, which is 46% higher than in 2010 and 360% higher than in 1990. By 2035, the biggest source of CO<sub>2</sub> emissions is the electricity generation sector (33%), followed by the domestic transport sector (24%) and the industry sector (21%).

Under BAU assumptions, Malaysia’s CO<sub>2</sub> emission intensity of GDP will likely show a reduction of 32% from 2005 to 2020, compared to the goal set by the government to reduce CO<sub>2</sub> emission intensity of GDP by 40% in the same period. Further efforts are recommended to improve the economy’s environmental sustainability, particularly in the power generation, transport and industry sectors.

The decomposition analysis in Table MAS1 indicates that prior to 2005 the total change in CO<sub>2</sub> emissions from fuel combustion was driven by change in GDP. From 2010 onwards, GDP impact on emissions will be offset by the decreasing energy intensity from energy efficiency measures in industrial structure.

Figure MAS7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

Table MAS1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.2%	-0.2%	-0.2%	-0.2%	-0.2%
Change in Energy Intensity of GDP	0.9%	-2.8%	-2.4%	-2.3%	-2.2%
Change in GDP	6.3%	4.5%	4.1%	4.1%	4.0%
<b>Total Change</b>	<b>7.5%</b>	<b>1.4%</b>	<b>1.5%</b>	<b>1.5%</b>	<b>1.5%</b>

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

Malaysia has achieved remarkable success in its economic development agenda, which is strongly underpinned by its energy sector, especially its oil and gas production. Malaysia's oil and gas reserves are modest in size and are gradually depleting. While efforts to discover and exploit new reserves are ongoing and have yielded encouraging success, Malaysia continues to transform its economic portfolio by strategically developing its strengths in sectors other than oil and gas — priority areas include financial services, wholesale and retail, palm oil and rubber production and processing, tourism, electrical and electronics manufacturing, business services, agriculture and healthcare.

In order to ensure long-term energy security, the economy is implementing new, long-term solutions for its energy needs. This includes intensifying energy efficiency initiatives to ensure more productive and prudent use of the remaining reserves, and enhancing efforts to develop viable new renewable energy resources, such as solar, wind, and biofuel. These efforts would also mitigate environmental ill effects caused by the energy sector, especially from the projected 46% increase in total carbon emissions over the outlook period.

## ALTERNATIVE SCENARIOS

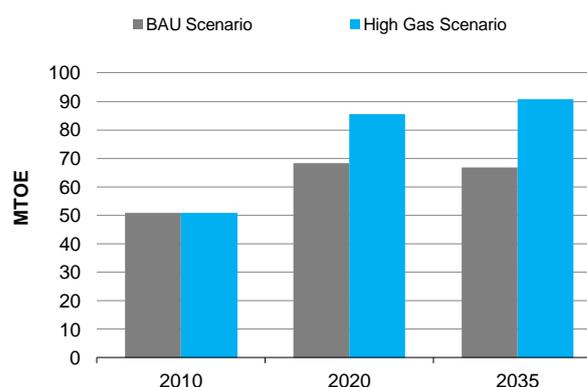
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Malaysia assumed the production increase shown in Figure MAS8, which is 36% by 2035. Two key assumptions were made in this scenario. First, a slight relaxation of the 3% restriction on gas production set under the National Depletion Policy 1980 to 4%. Second, successful commercialization of new natural gas discoveries—this includes Block SB303 in offshore Sabah (Lundin, 2012). These very recent gas discoveries were not included in the BAU assumptions.

Figure MAS8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

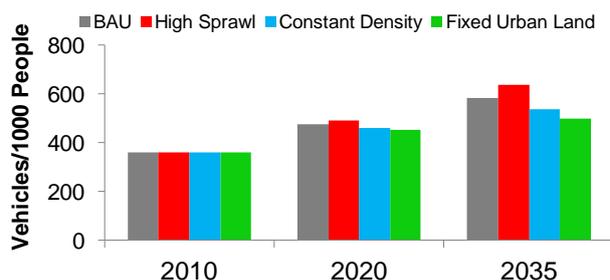
Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. The Malaysian Government aims to have a balanced electricity generation mix to avoid dependency on a single fuel. Figure MAS6 shows natural gas already occupies a large portion (62% in 2010) of the generation mix. In line with Malaysia's policies, this alternative scenario assumes that in a high gas availability situation the economy would seek to maximize economic benefits by exporting the additional gas via its LNG and pipeline facilities, rather than increasing natural gas utilization in the power sector. For this reason, Figures MAS9 and MAS10 (which show changes in electricity generation and the resulting change in emissions) were not included.

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure MAS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. By 2035, the difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to BAU, and about 8% lower in the Constant Density scenario and 14% lower in the Fixed Urban Land scenario.

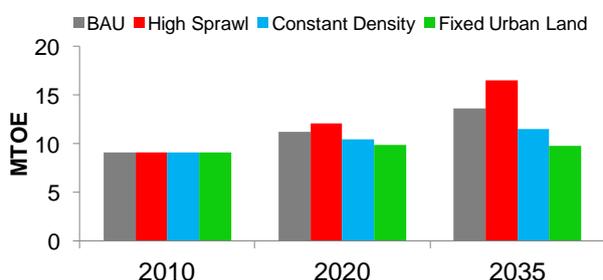
**Figure MAS11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure MAS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Better urban planning has an even more pronounced impact on light vehicle oil consumption than on vehicle ownership because compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil consumption would be 21% higher in the High Sprawl scenario compared to BAU in 2035, and about 16% and 28% lower in the Constant Density and Fixed Urban Land scenarios, respectively.

**Figure MAS12: Urban Development Scenarios – Light Vehicle Oil Consumption**

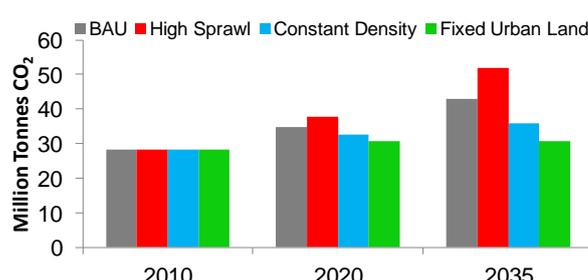


Source: APERC Analysis (2012)

Figure MAS13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

The benefits of urban planning in reducing the number of vehicles, oil consumption and CO<sub>2</sub> emissions are quite significant, and Malaysia as a developing economy would do well to incorporate energy saving urban designs in their city planning policies.

**Figure MAS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



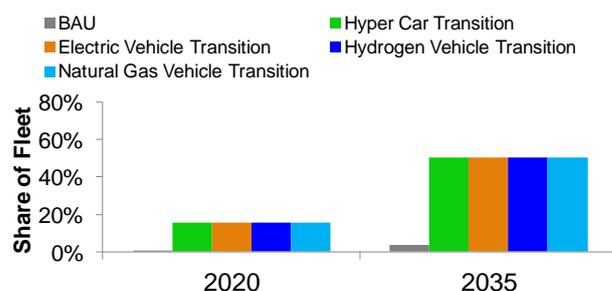
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure MAS14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 50% compared to about 4% in BAU. The share of conventional vehicles in the fleet is thus only about 50%, compared to about 96% in the BAU scenario.

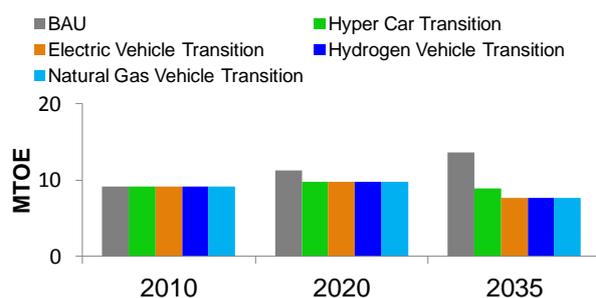
**Figure MAS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure MAS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 44% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU in 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 27% by 2035—even though these highly efficient vehicles still use oil.

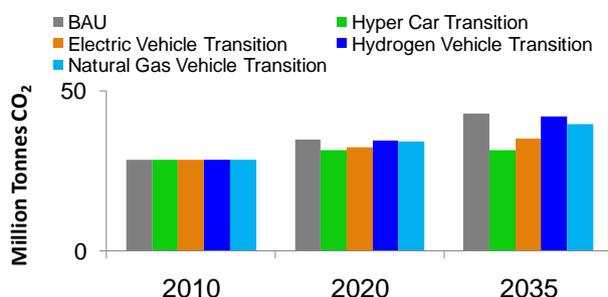
**Figure MAS15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure MAS16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure MAS16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Malaysia, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emission reduction, with an emission reduction of 27% compared to BAU in 2035. The Electric Vehicle Transition scenario would be second, offering a reduction of 18% compared to BAU in 2035. The Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer lower emission reductions (8% and 2% respectively).

Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption, while in the other alternative vehicles oil combustion is replaced by other fuels—namely electricity for electric vehicles, hydrogen for hydrogen vehicles and gas in natural gas vehicles. Thus, additional demand for electricity and hydrogen generation would produce more CO<sub>2</sub> emissions and

this will offset some of the benefits gained from oil replacement. However, since Malaysia's electricity generation relies heavily on natural gas, electric vehicles tend to do better in terms of CO<sub>2</sub> emissions than they do in other economies that rely more on higher-emitting coal for electricity generation.

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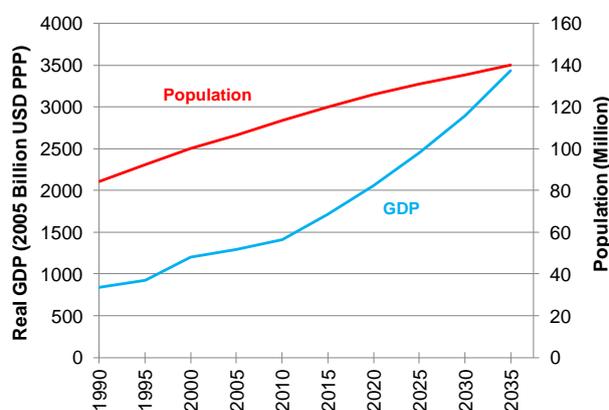
# MEXICO

- *By sustaining its crude oil production, Mexico is likely to remain a large oil producer and exporter in the future.*
- *Even though Mexico is expected to be a net gas importer throughout the outlook period under business-as-usual assumptions, the full extent of Mexico's shale gas resources remains unknown. Better knowledge of these resources could change Mexico's gas outlook considerably.*
- *CO<sub>2</sub> emissions are projected to grow 56% in the outlook period with the economy's final use sectors accounting for 55% of those emissions by 2035. Mexico's CO<sub>2</sub> intensity is expected to decline much faster than its final energy intensity.*

## ECONOMY

Mexico is legally constituted as a republic and politically divided into 31 states and one federal district. It is geographically located in North America and is one of APEC's three Latin American economies. Bordered by the United States (US) to the north and Belize and Guatemala to the south, the Mexican territory, of around 1.96 million square kilometres, is rich in resources. It encompasses a wide variety of climatic conditions, ranging from very dry with high temperatures in the north, to very humid with high temperatures in the south, to mild in the centre and warm on the coasts (SMN, 2011). Due to its abundant and complex ecosystems, Mexico is one of the 12 'megadiverse' economies in the world (UNEP, 2002).

**Figure MEX1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

As depicted in Figure MEX1, the economy's total population of around 112 million in 2010 (Inegi, 2010) is projected to grow moderately, at an annual rate of 0.8%, to reach 140 million by 2035. Around 78% of Mexico's population live in urban areas and the remaining 22% live in rural areas (UN, 2009).

The largest urban areas are Mexico City, Guadalajara and Monterrey. While Greater Mexico City formed by the Capital City (Distrito Federal) and its surrounding metropolitan areas (Zona Metropolitana del Valle de México) represents only

0.1% of the Mexican territory, it accounts for as much as 25% of the economy's GDP. With a population close to 20 million, Mexico City is one of the top megacities in the world (UN, 2008).

Mexico's economic growth is expected to be moderate, with real GDP expanding at an average of 3.6% per year from 2010 to 2035 (see Figure MEX1). GDP per capita is expected to grow less dynamically, with a 2.8% average annual growth rate over the same period. In spite of being an OECD member since 1994, Mexico's GDP per capita was the lowest among the member economies in 2010 (IMF, 2011) and poverty reduction is one of the economy's major challenges—46% of Mexico's population are still considered poor and 10% live under extreme poverty conditions (Coneval, 2011). According to the United Nations Human Development Index (which measures progress in terms of human well-being rather than in pure economic terms) though, Mexico is considered a High Human Development economy, ranked 57th in the world and fifth in Latin America (UNDP, 2011).

Mexico is an export-driven economy, the second largest in Latin America and the 14th largest in the world (IMF, 2011). Roughly 80% of its total exports go to the US. Crude oil and manufactured goods (mostly machinery and vehicles) are Mexico's main exports. In 2010, crude oil, machinery and vehicle manufactures accounted respectively for 14%, 23.9% and 21.8% of Mexico's total exports (SE, 2011).

The energy sector, and particularly the oil industry, is critical to the economy. Revenues and taxes from the state-owned oil company provide nearly one-third of the total government revenue, from which Mexico's social development is mainly funded (Inegi, 2011; SHCP, 2011). In addition to exports, remittances from Mexicans working abroad are especially important. They not only constitute the second largest income source but, since 2009, have surpassed foreign direct investment inflows (Banxico, 2011).

The services sector is the main component of Mexico's GDP, accounting for 65% in 2010; industry and agriculture represent 31% and 4%, respectively. Along with the export-oriented industries described above, food products, chemicals, cement, beverages and tobacco are Mexico's most distinctive industries (Inegi, 2011). The most energy-intensive industries are iron and steel, cement, sugar, chemicals and mining; their joint energy demand amounts to half of the energy demand of Mexico's industry sector (Sener, 2011a).

Due to its location, Mexico is prone to natural disasters, with floods, hurricanes, droughts and even frosts being common. As the Mexican territory lies between several tectonic plates, the incidence of earthquakes is high, with most of the major ones stemming from the Pacific Coast (SSN, 2011). Moreover, Mexico has many volcanoes, several of them with little activity and close to major urban centres. An example is Popocatepetl, whose ash emissions have occasionally affected Mexico City's air quality, most recently during the second quarter of 2012 (Segob, 2012).

Road transport dominates passenger transport in Mexico, carrying more than 97% of all passenger trips. The remaining passenger transport is evenly split between air and (mostly short-distance) rail; marine transport has little significance. The economy has a comprehensive road infrastructure of almost 372 000 kilometres spread across the territory. Only 37% of the roads are paved (predominantly federal and state toll highways); the rest are gravel or unsurfaced (SCT, 2011).

As Mexico's vehicle ownership level of less than 300 units per 1000 people is well below saturation, it is expected that in the next few years vehicle growth will be robust due to increasing population and per capita income.

The recent expansion of bus-rapid-transit corridors, subway (metro) and local train systems in major urban centres such as León and Mexico City has helped to improve mass transport in the economy. However, most urban transport networks are still served by traditional systems where many small buses with drivers paid on a daily basis compete for customers. This has led to an inefficient oversupply of obsolete vehicles that increase traffic congestion, commuting times, customer fares and greenhouse gas (GHG) emissions. Domestic freight transport is also dominated by road carriers, at around 85%; rail, marine and, marginally, air transport account for the remainder (SCT, 2012). The transport sector alone accounts for the majority of

emissions in final energy demand—the sector is responsible for two-thirds of the emissions.

Mexico is one of the world's top 10 automobile manufacturers. Nonetheless, the majority of the vehicles produced are exported and only about 20% are sold domestically (BBVA, 2012), with most of Mexico's vehicle fleet being imported.

Although Mexico's weather conditions are diverse, most of its territory enjoys warm and consistent temperatures. The hottest areas in the territory are located in the humid south, along the coastlines and particularly in the dry north; and while they call for the intensive use of air conditioning and cooling equipment, their use is, still far from saturation. On the other hand, in spite of cold winters and occasional snowfalls in the north and high-altitude areas, the use of central heating in the economy's households is uncommon.

## ENERGY RESOURCES AND INFRASTRUCTURE

Mexico's geographical position provides the economy with large energy resources including crude oil, natural gas, coal and uranium as well as hydro, wind and solar resources for power generation. In 2010, Mexico's proven primary energy reserves were 10.2 million barrels of crude oil (11.4 if gas liquids are included), 0.35 trillion cubic metres of natural gas, 1.21 billion tonnes of coal and 1.3 thousand tonnes of uranium (Pemex, 2011b; BP, 2011).

Mexico is among the top oil producer economies and is a net crude oil exporter. Around 53% of its total indigenous crude oil production of 2.56 million barrels per day is sent overseas, mainly to the US. In 2010, Mexico was the second largest oil exporter to that economy (USEIA, 2012; Pemex, 2011b).

By law, hydrocarbon resources are exclusively exploited by *Petróleos Mexicanos* (Pemex), the state-owned oil company, ranked as one of the largest in the world. The company is Mexico's sole upstream and downstream agent and is responsible for the final distribution of most oil products (liquefied petroleum gas, or LPG, is among the exceptions). At a broader level, Pemex is of the utmost importance as it represents Mexico's most significant taxpayer (Pemex, 2011a).

For its oil reserves Mexico is ranked 17th in the world. Its production, which comes primarily from its offshore southern regions, is characterised by a predominance of heavy (55%), light (32%) and extra-light (12%) oil types. One supergiant field, Cantarell, accounted for as much as 63% of Mexico's oil production at its peak production in 2004. However,

due to its continuing natural decline, Pemex's efforts have been aimed at discovering and exploiting other fields to offset this output loss and the company's focus has shifted to production and investments in new areas in the oil-rich southern basins in an attempt to stabilise total crude oil output. Nonetheless, these new areas are more technically complex, such as the offshore Ku-Maloob-Zaap and onshore Chicontepec (Aceite Terciario del Golfo) fields. In addition, due to the permanent legal restriction on oil producers other than Pemex and to that company's severe budgetary constraints, the development of Mexico's oil resources has been hindered. This is the case with Mexico's considerable deepwater oil potential, whose production has been delayed and it is not expected to begin until 2015 (Pemex, 2012).

Even though Mexico is a big oil producer, the lack of sufficient domestic refining capacity forces the economy to be a major oil products importer, especially of gasoline. Nearly half of the total gasoline demand is met by imported stock.

Mexico is also an important natural gas producer of 0.20 billion cubic metres per day, of which roughly 65% is associated with crude oil and the remaining 35% is non-associated gas. For its natural gas reserves, Mexico was ranked 33rd in the world in 2010 (Pemex, 2011b). Historically, the Burgos Basin has been the main producer of non-associated natural gas; the offshore oil fields, including Cantarell, have been the most significant associated gas sources (Pemex, 2011b). In addition, with the recent release of a world assessment of shale gas resources by the US Department of Energy (USEIA, 2011), Mexico's shale gas potential has attracted domestic and international attention. Its shale gas resources were ranked fourth among the economies studied.

Despite being a significant gas producer, Mexico is not self-sufficient in natural gas. This is due to an increasing demand for natural gas in the oil industry, the electricity sector and the residential and commercial sectors for heating and cooking purposes. Expanding distribution grids for natural gas have helped it to replace other traditionally-used fuels like LPG. Nonetheless, some imports are necessary due to infrastructure and logistics reasons; Mexico's main natural gas pipeline connecting the production areas to the consuming centres does not extend to the north-west region. Natural gas imports from the US are required to meet that demand.

Unlike the oil industry, where all major activities are carried out by Pemex and its subsidiaries, the natural gas industry in Mexico allows private participation to some extent, namely in the import,

export, transport, storage and distribution activities. This has helped to promote competition and infrastructure construction, including LNG (liquefied natural gas) terminals. Under the current regulations, the awarding of a distribution permit grants a single company exclusivity in a set area for a long-term period and is conditioned to the fulfilment of investment pledges. In an attempt to protect customers and to prevent vertical monopolies, companies cannot be awarded permits for both transport and distribution activities. So far, natural gas distribution grids are present in 20 areas of Mexico, including its major cities and many significant industrial clusters (Sener, 2010b).

To support and diversify its natural gas supply, Mexico has three LNG regasification facilities; one on the Gulf of Mexico and two on its Pacific Ocean coastline. In the northern Gulf of Mexico, the Altamira LNG Terminal, with a maximum regasification capacity of 21.5 million cubic metres per day (mcmd), supplies natural gas to combined-cycle public power plants. On the Pacific coastline of the Baja California State, close to the US, the Ensenada LNG Terminal (Energía Costa Azul) operates with a maximum regasification capacity of 36.8 mcmd. Mexico's third LNG terminal, Terminal KMS on the southern Pacific coastline at Manzanillo, Colima is under construction, with a maximum regasification capacity of 14.2 mcmd. It is expected to start operations during 2012, mainly to service public power plants. Once the three terminals are operating, Mexico's LNG storage capacity will amount to 72.5 million cubic metres per day (Sener, 2010b).

Coal consumption is relatively low in Mexico. Most of the economy's recoverable coal reserves of 1.21 billion tonnes are located in the north-eastern state of Coahuila, with some significant additional resources in Sonora (in the north-west) and Oaxaca (in the south). Around 70% of the recoverable reserves are of the anthracite and bituminous types, while 30% are sub-bituminous and lignite (BP, 2011). Coal production is around 11 million tonnes a year—more than 80% is thermal coal, the rest is coking coal. Mexico's main use for coal is as a fuel for thermal power plants (thermal coal). Coking coal is used for feeding the iron and steel industry's furnaces. Coal imports are required as production only meets about half the economy's demand (Sener, 2011a).

In the case of electricity, as in the oil sector, Mexico manages all its transmission, transformation, distribution and public service activities through the state-owned Power Federal Commission (CFE for its acronym in Spanish). On 11 October 2009, as part of the Mexican Government's action plan to improve

energy efficiency in the power sector, the state-owned Luz y Fuerza del Centro electric power utility, which was responsible for servicing Mexico's central area including Mexico City and its metropolitan area, was abolished by presidential decree. Due to its poor efficiency and the considerable public financing required to support its operations, the utility had become a burden for Mexico's public budget and its energy sectors (DOF, 2009). As a result, the operation of its service territory was taken over by CFE, which now stands as the only public power utility in the economy.

CFE is in charge of the electricity sector's planning and manages all the electricity generated by itself and the independent power producers (IPPs) that operate in a segment of the industry open to the private sector. The Mexican Electricity System (SEN for its acronym in Spanish) is made up of three grids; the main one is comprehensive and spreads across most of the territory. The other two grids are located in the north and south of the Baja California State. Currently these three grids are isolated from each other although the northern Baja California grid is expected to be connected with the main grid by 2014 (CFE, 2011).

The northern Baja California grid is connected to the US at two points, allowing for electricity imports and exports depending on each economy's electricity needs. In addition to the US, Mexico exports electricity to the neighbouring economies of Belize and Guatemala. Exports and imports of electricity are modest and represent less than 1% of the economy's total electricity generation. Mexico's economy-wide reserve margins are over 40% due to planning decisions based on estimates that turned out to be above the actual demand (CFE, 2011). Thus, Mexico's electricity supply and SEN's reliability are considered strong.

Mexico's overall electrification rate is 97.7% of its total population, being 98.9% in the urban centres and 93.1% in rural areas (Sener, 2011b). As the legal framework mandates electricity supply to be universal except when economic or technical factors are present, in 2010 the government launched a project to bring electricity to Mexico's poorest communities through the installation of solar panels. The project, partially funded by the World Bank, looks forward to providing electricity over a 5-year span to 50 000 households in 2500 isolated communities located in Mexico's districts with the lowest Human Development Index values (Sener, 2010a).

The total installed electricity generation capacity for public service was 52 945 megawatts (MW) in 2010. Around 77.5% came from CFE, and the

remaining 22.5% from IPPs, which sell their electricity to CFE to be supplied into the SEN. Roughly 74% of Mexico's power plant capacity is based on fossil fuels, with natural gas alone accounting for a little over half of that share. The remaining 26% is spread over nuclear, NRE (new renewable energy) and hydropower, the latter of which represents 22% of total capacity (Sener, 2011b).

SEN's concern with diversification of supply and sustainability issues has caused it to promote low-carbon technologies for power generation (especially more combined-cycle power plants and the replacement of fuel-oil based thermal power plants), the use of renewable energy, and some cogeneration opportunities. According to the SEN's expansion plan (CFE, 2011), Mexico's renewable-based electricity generation will increase in the next few years, building on the economy's promising potential for hydro, wind and geothermal electricity generation.

## ENERGY POLICIES

Under the current legal framework, Mexico's Ministry of Energy (Secretaría de Energía, Sener for its acronym in Spanish) is responsible for the economy's energy policy. In 2007 and based on the National Development Plan 2007–2012, Sener launched the Energy Sector Program 2007–2012 to match the Presidential 6-year term. The main energy policy goals contained in the document aimed for the secure supply of the energy required for development at competitive prices, while minimising environmental impacts, operating at a high standard and promoting energy efficiency and diversification (Sener, 2007).

Considered the most significant recent development in Mexico's energy policy, the Energy Reform passed in 2008 included a set of laws and reform initiatives to strengthen the energy sector and to grant greater autonomy to Pemex.

With these reforms, a new document to guide energy sector policy in the long term was created. Mexico's National Energy Strategy (ENE for its acronym in Spanish) sets out the long-term vision for a 15-year span and is the reference point for all energy policies. The strategy focuses on three critical areas: energy security, economic efficiency and environmental sustainability. It also provides an insight into issues and topics that could shape the energy industry in the future. Although integrated and published annually by Sener, the ENE is developed through the collaboration of a number of governmental institutions, universities, research institutions, independent experts and representatives

of Mexico's states and legislative powers, to ensure all relevant perspectives are reflected in the document.

The most recent edition of this document, issued in February 2012, explores several possible scenarios for Mexico's energy policy (business-as-usual, or BAU, and ENE-optimistic) and sets out several objectives covering the energy sector's major activities (hydrocarbons, electricity, renewable energy, energy efficiency, sustainability and technological research) to be achieved by 2026. By that year, its long-term policy aims for crude oil production of 3.4 million barrels per day, a replacement ratio of crude oil's proved reserves of more than 100%, natural gas production of 0.32 billion cubic metres per day, and a reduction in flaring and losses during gas extraction of 0.8% of the gas produced. In the downstream activities, the goals are to increase the natural gas transportation capacity and to boost petrochemicals production.

In comparison to previous documents, the latest edition of the ENE includes production from Mexico's shale gas resources by 2016. For this to happen, ENE assumes changes in the regulatory and business environment will be made to provide an incentive to develop this unconventional gas supply. While under the ENE's BAU scenario only one shale gas play will be developed with an output of 28 mcmd by 2026, its optimistic scenario considers developing another play providing an output of 92.9 mcmd by 2026 (Sener, 2012).

In compliance with these policies, Pemex defined the company's future priorities in its 2012–2016 Business Plan, including plans for several major projects it intends to carry out. Pemex looks forward to finding and developing new reserves, optimising its hydrocarbon and petrochemical production levels and ensuring their competitive and efficient supply in the economy (Sener, 2011b).

In the electricity sector, the economy's long-term energy policy calls for a reduction of total power losses from 11% in 2010 to 8% in 2026. For CFE to reduce its power losses, more aggressive measures against electric power theft will be needed. Power theft is not uncommon in Mexico, and represents one of the major causes of the economy's power losses. By 2026, Mexico's energy policy also aims to achieve a reduction in the reserve margin to 13%, and a 2.1% increase in the length of the power transmission network. This effort will include not only building new lines, but also replacing many of the existing ones that are reaching the end of their life cycle. Another objective is to improve energy efficiency enough to achieve a 15% or more energy savings over the government's BAU projection. This

will be accomplished mainly through the allocation of more resources to strengthen the planned energy efficiency projects (Sener, 2012).

The long-term policy also demands an increase in the share of non-fossil-fuels electricity generation (NRE, large hydro and nuclear) from around 26% in 2010 to 35% by 2026. Natural gas based technologies have been favoured since the early 2000s for power generation, and this trend is expected to continue. However, other alternatives such as renewable energy and low-carbon technologies will play a significant role in Mexico's electricity generation in the future (Sener, 2012). Natural gas power plants have been preferred primarily due to relatively low prices and low emissions for natural gas, but also because of the increasing supply of natural gas in Mexico, the lower construction investment, and the higher thermal efficiency in comparison with other fuels (CFE, 2011).

Even though Mexico does not rule out nuclear energy for meeting its future electricity demands, the ENE only includes nuclear energy expansion in its alternative scenarios. Its BAU assumptions did not consider any additions to the economy's nuclear-generated power capacity, which consists of the Laguna Verde power plant.

To promote the use of renewable energy throughout the economy, Mexico developed a new regulatory framework as a result of the 2008 Energy Reform. This includes new legal and institutional provisions to promote renewable energy and biofuels, through several strategies. The passing of the Law for Renewable Energy Utilization and Energy Transition Funding led to the creation of a National Strategy for Energy Transition and Sustainable Use. This strategy will promote policies, programs, actions and projects focusing on the increased use of low-carbon technologies, the promotion of energy sustainability and efficiency, and the reduction of Mexico's dependence on hydrocarbons. Created from a special tax levied on Pemex's revenue, the Law also provided for the creation of the Trust Fund for Energy's Transition and Sustainable Use. The fund's objective is to finance scientific and applied research projects dedicated to low-carbon technologies, the diversification of energy sources, renewable energy sources and energy efficiency.

The implementation of various other projects in collaboration with international organizations has helped to expand renewable energy in Mexico. In addition to the project for the electrification of poor communities mentioned above, with the aid of the German agency for International Cooperation, the program for solar water heating was launched in

2007. The objective of this program is to install 1.8 million square metres of solar collectors for water heating purposes in residential, commercial and agriculture sectors by providing the technical support, and by coordinating with the major stakeholders involved in the production and use of this technology.

Mexico has had energy efficiency programs since 1989 and has public institutions that encourage efforts in energy efficiency and conservation. The National Commission for the Efficient Use of Energy (Conuee) is responsible for promoting the programs and for providing technical advice in energy efficiency. Other institutions, such as the Trust Fund for Electricity Savings (FIDE), provide finance for energy audits and assessments, and facilitate the acquisition and installation of energy-efficient equipment.

Some of the energy efficiency policies currently being carried out by Mexico are: the Program for Energy-Saving Household Appliances Replacement, to replace freezer and air conditioning equipment at least 10 years old with energy-efficient new appliances through a preferential-rate loan from the Mexican Government repaid through the power utility bill; and the Program for Sustainable Light, to replace up to four traditional incandescent bulbs per household with four energy-efficient lamps free of charge. In addition, the Official Mexican Standards specify the minimum energy efficiency requirements for an electric product to be sold on the Mexican market.

To control the economy's inflation and to reduce the social impact of energy price increases, the Mexican Government subsidizes the fuels most used by families, such as electricity (restricted to low-consumption residential tariffs), LPG, gasoline and diesel. In the case of gasoline and diesel, the government applies a monthly slippage scheme. The scheme seeks to allow Mexico's prices to catch up with their US counterparts to avoid economic distortions, to reallocate subsidies to social projects, to promote lower imports through lower demand and to reduce emissions associated with fuels combustion. The slippage scheme works by increasing Mexico's gasoline and diesel prices by a few cents at a time, with the aim of gradually closing the gap between domestic and international prices (IISD, 2010). Since these fuel subsidies are general rather than targeted to the lowest-income population, they can promote inefficient or wasteful consumption, along with increased fuel demand and emissions without necessarily improving poor people's incomes. They also require the expending of considerable financial resources that could otherwise

be directed to more urgent government priorities such as social programs.

Recognizing climate change as one of the major global and domestic challenges, the Mexican Government considers it to be a central policy concern. The economy introduced a National Climate Change Strategy (ENCC for its acronym in Spanish) in 2007 for mitigation and adaptation to climate change, and published the Special Climate Change Program 2009–2012 (PECC for its acronym in Spanish) in 2009.

As the energy sector is the main contributor of GHG emissions in Mexico, the PECC established actions to achieve the mitigation desired in two areas: oil and electricity production and final-demand efficiency and savings. In the short term, the PECC set a specific mitigation goal to be achieved by 2012—to avoid 50.6 million tonnes of carbon dioxide equivalent, with the energy sector accounting for 57% of those emissions. On the other hand, two ambitious aspirational long-term goals were also integrated in the document. These strive to reduce Mexico's total GHG emissions by 20% by 2020 and by 50% by 2050, compared with its emission levels in 2000 (Semarnat, 2009).

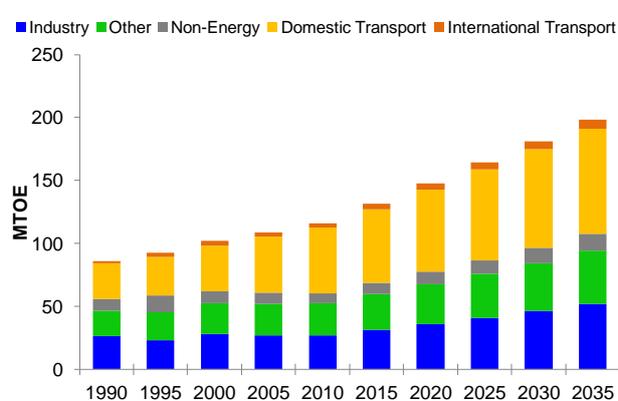
As an update to this document, it is worth mentioning that on 1 December 2012 Mexico had a new president, from a different political party than his last two predecessors and for the period up to 2018. While no formal plans had been announced at the time of closing this document, President Peña Nieto had announced the government's intentions of attaining a substantial reform in the energy sector, to turn it into an effective lever for Mexico's transformation (Presidencia de la República, 2012).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

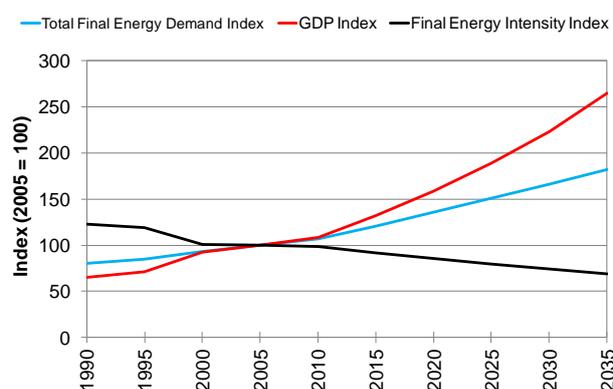
Under a BAU scenario, Mexico's final energy demand is expected to grow 70%, from 112 million tonnes of oil equivalent (Mtoe) in 2010 to 191 Mtoe by 2035. Sector shares are expected to remain fairly constant from 2010, with domestic transport accounting for the largest share of the demand (42%) followed by industry (26%), 'other' (residential, commercial and agriculture) (21%), non-energy (7%) and international transport (4%) in 2035. From 2005 to 2035, final energy intensity is expected to decline by 31%.

Figure MEX7: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure MEX3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

The industry sector's energy demand is projected to grow 92% over the outlook period, increasing from 27.1 Mtoe in 2010 to 52.1 Mtoe by 2035. By energy source, shares in 2035 will remain fairly similar to those in 2010, with decreasing contributions from oil and NRE and increasing contributions from gas and electricity.

Reflecting the predominance of machinery in Mexico's industry composition, electricity is expected to continue as the main energy source with almost 39% of the industry sector's energy demand by 2035. Natural gas is expected to have the second largest share, at 37%. Apart from oil, with an expected share of 19%, the remainder will be made up by coal and NRE. These latter two energy sources are mainly used in the most energy-intensive industries: coal, in the cement and steel industries and NRE (as biomass) in the sugarcane industry. Industry energy intensity is projected to decrease 27% from 2005 to 2035.

### Transport

Domestic transport is expected to remain the largest energy demand sector in Mexico with roughly 42% of the total energy demand in 2035. From 2010 to 2035 this sector is estimated to grow 61%. Given the lack of incentives for the use of alternative vehicles, by 2035 nearly all the sector's energy demand (95%) will be based on oil fuels (gasoline and diesel). The future chances for developing significant demand for energy alternatives other than compressed natural gas (CNG) and NRE (biofuels) are small.

Energy demand for CNG and NRE (in the form of bioethanol and biodiesel) is expected to grow significantly, expanding 48 and 5 times respectively, by 2035. The growth assumptions for CNG are based on favourable expectations for the relative price of CNG compared to gasoline and on tighter environmental standards calling for cleaner fuels, especially in mass transport vehicles. Nonetheless, in spite of this dramatic growth, CNG's share in the transport energy mix by 2035 will still be small, accounting for around 1%. In the case of NRE in the form of biofuels, the Mexican Government plans to replace gasoline's conventional oxygenates with bioethanol in the city of Guadalajara, to comply with the mandatory 2.7% oxygenation blending (Semarnat, 2006). Along with the ongoing early development of biodiesel-based transport solutions across the economy, this plan will push forward biofuels' demand in the long term.

On the other hand, although the strategies in the National Program for Sustainable Use of Energy (Pronase) issued in late 2009 called for an increase in fuel efficiency and an improvement in best practices for new vehicles added to the national fleet, Mexico lacks mandatory fuel efficiency standards. The issuing of such standards during the outlook period would be helpful not only in driving down energy demand, but also in reducing gasoline imports and decreasing CO<sub>2</sub> emissions.

## Other

The ‘other’ sector’s energy demand is projected to increase 65%, from 25.4 Mtoe in 2010 to 41.8 Mtoe by 2035. By the end of the outlook period, the combined energy demands of the residential, commercial and agriculture sectors are expected to represent around 21% of the total final energy demand. Natural gas will be the fastest-growing energy source, with its demand almost doubling by 2035. This will be followed by electricity demand increasing by 87%, oil (mostly as LPG) by 85% and NRE (in the form of firewood) showing very little growth.

Unlike other sectors whose energy composition is projected to remain stable from 2010 to 2035, in this sector the shares of the various fuels are expected to change. While the shares for oil (in the form of LPG), natural gas and electricity will increase, the share of NRE in the ‘other’ sector’s total energy demand is expected to decrease. By 2035, this sector’s energy demand is estimated to be made up by oil (47%), electricity (33%) and natural gas (4%). NRE’s share (as non-commercial firewood) will be gradually replaced by commercial energy options, and will represent only 16% of the energy demand in 2035, down from a 25% share in 2010. Unlike other APEC economies, Mexico depends heavily on oil products, mostly LPG, to meet the energy demand in the residential and commercial sectors.

This situation is explained by a natural transition to more convenient energy sources. As new energy distribution infrastructure reaches more markets and more energy options are available for consumers, a shift away from non-commercial fuels is expected. In Mexico’s case, these circumstances have historically favoured the wide distribution of LPG to replace firewood. Although the recent expansion of distribution grids has provided access to natural gas in more areas, their development is still limited and they have not significantly reduced the use of LPG.

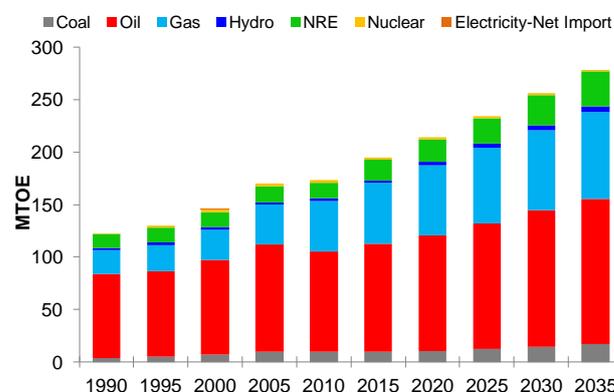
It is worth noting that due to Mexico’s energy efficiency programs and policies being especially focused on the residential sector in recent years, the ‘other’ sector’s energy intensity reduction in the outlook period is expected to be slightly better than that in the industry and transport sectors, with a total improvement of 37% from 2005 to 2035.

## PRIMARY ENERGY SUPPLY

Mexico’s primary energy supply is expected to increase by 61% in the 2010–2035 outlook period. The predominance of fossil fuels is expected to continue, with coal, oil and gas jointly accounting for 86% of primary energy supply by 2035, with the rest

provided by NRE (12%), hydro (2%) and nuclear (less than 1%). From 2005 to 2035, Mexico’s primary energy intensity will decline 38%.

**Figure MEX4: BAU Primary Energy Supply**



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As one of the world’s major oil and gas producers and exporters, and given its potential resources for these products, Mexico’s oil production is assumed to increase during the outlook period. Production is expected to reach its peak by 2025 with 200.4 Mtoe (3.3 million barrels per day) and to sustain this output until 2035. This represents an average annual growth of 1% from 2010 to 2035. It is expected the economy will remain a net oil exporter for the outlook period.

In contrast, Mexico will remain a net gas importer throughout the outlook period, with the import gap increasing from 2020 to 2035. This will occur in spite of an average annual growth of 1.4% in natural gas production from 2010 to 2035. However, additional shale gas production beyond the planned levels could affect these outcomes.

In this regard, the development of Mexico’s shale gas resources poses several uncertainties. Although the economy is including one or two shale gas plays in its long-term energy policy, the available data on its resources is based on external information and Mexico still lacks its own studies to assess accurately the location and scale of its shale gas reserves. In addition, Pemex’s budget is not only insufficient for addressing effectively all of its projects, but more than 90% of those financial resources are absorbed by its oil exploration and production activities. This leaves a very low share to be allocated for other operations and projects.

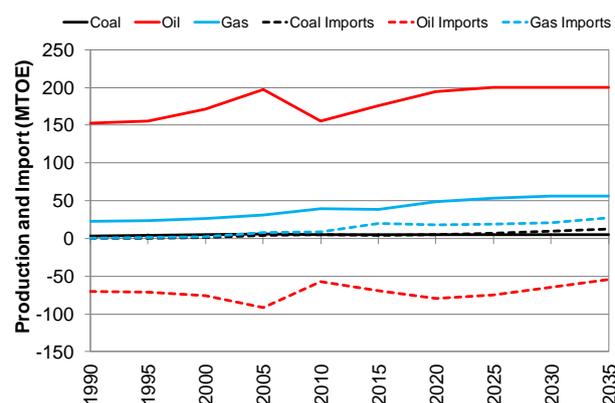
Aggravating this situation is the fact that hydrocarbons exploration in Mexico is exclusively reserved for the state. While private participants are currently undertaking some upstream activities under special contracting schemes, their operations are

limited and the production planning and decisions are still carried out by Pemex. This limits flexibility, compared to standard practices in the global industry.

In contrast, a key factor for the booming shale gas production in the US is the existence of a plethora of predominantly small and mid-sized competing producers, site builders and service providers who can afford capital-intensive drilling and hydraulic fracturing in many wells dispersed across large areas (USDOE, 2009). This industry structure has allowed participants to bear higher capital costs compared with conventional gas production and to have greater organisational flexibility to come up with cost-effective technological solutions, to afford infrastructure construction, and to adapt to the market fluctuations.

The above conditions are totally the opposite to the ones prevailing in Mexico, where decisions tend to be centrally-made and politically-driven. As a result, budgets and project planning tend to favour conventional production, and to restrain investment in new technology and research and development. Unless policymakers are able to design a more competitive and attractive environment for shale gas production, it seems likely that Mexico’s unconventional gas potential will not be fully developed. This in turn will hamper its aspirations to reverse its position as a gas importer in the future, restraining its energy security and the economic benefits that shale gas could bring.

**Figure MEX5: BAU Energy Production and Net Imports**



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

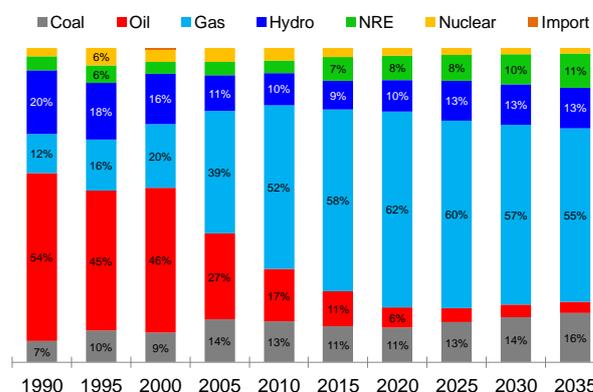
**ELECTRICITY**

Power generation in Mexico is projected to increase 72% in the outlook period. By 2035, it is expected that nearly three-quarters of the total electricity generation will remain based on fossil fuels, primarily natural gas. The rest will be supplied by hydro, NRE and nuclear energy power plants.

From 2010 to 2035, it is estimated that the largest growth by power generation source will be experienced by NRE at 356%. In contrast, oil-based generation is expected to drop by 63.5%. During the outlook period, NRE capacity will be based on wind, geothermal, mini-hydro and biomass. Based on SEN’s expansion plan, solar energy growth is assumed to be limited, although particular projects carried out by private investors could be possible in the future.

Renewable energy and low-carbon technologies will play a growing role in Mexico’s power generation over the coming years. Altogether, non-fossil sources (hydro, NRE and nuclear) are expected to expand their share in Mexico’s power generation from 18% in 2010 to 25% by 2035. This is especially significant due to the projected growth in demand for the same period. However, this scenario suggests the Mexican Government’s target of 35% of total electricity generation based on these technologies might not be accomplished. Technical issues as well as financial constraints (such as the higher costs of technology development and of the construction of needed transmission infrastructure) might limit NRE’s output from growing to the targeted levels.

**Figure MEX6: BAU Electricity Generation Mix**



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

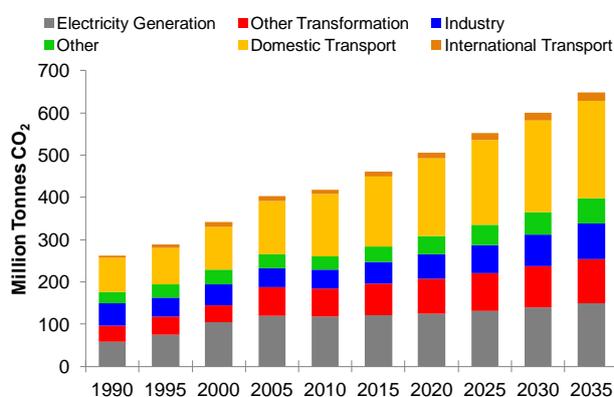
**CO<sub>2</sub> EMISSIONS**

CO<sub>2</sub> emissions in Mexico’s energy sector are projected to increase 55% from 2010, to reach around 649 million tonnes of CO<sub>2</sub> by 2035. Final-use energy demand will contribute 58% of these emissions, and the economy’s energy transformation sectors will account for the remaining 42%.

By fossil fuel, emissions from coal consumption are expected to have the largest increase in the outlook period (77%), followed by gas and oil (70% and 46%, respectively). The share of each of these sources in the total emissions is estimated to remain fairly constant over the outlook period. By 2035,

emissions from oil consumption will make up the majority (nearly 60%) of the total emissions, followed by gas (30%) and coal (10%).

**Figure MEX7: BAU CO<sub>2</sub> Emissions by Sector**



Source: APERC Analysis (2012)

From the results of these projections, shown in Figure MEX7, it seems that Mexico's long-term strategy towards lower-carbon electricity generation will pay off. The electricity sector's CO<sub>2</sub> emissions will grow only 26% in the outlook period, with their share in the total energy sector emissions dropping from 28% in 2010 to 23% by 2035. This may be explained by Mexico's long-standing policy to decrease oil-based power generation and to promote combined-cycle gas technologies. In this case, it is expected that the emissions from oil-based (diesel and fuel oil) power plants will decrease roughly 66% during the outlook period.

In contrast, in the final demand sectors, emissions will grow more quickly. Industry will have the fastest growth in emissions, 91% from 2010 to 2035, although the transport sector will account for 61% of final demand emissions by the end of the period.

As shown in Table MEX1, emissions resulting from Mexico's GDP growth will be partly offset by energy intensity reductions and small reductions in the CO<sub>2</sub> intensity of energy.

**Table MEX1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion**

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.6%	0.4%	0.0%	-0.1%	-0.2%
Change in Energy Intensity of GDP	-0.6%	-1.3%	-1.6%	-1.6%	-1.6%
Change in GDP	2.9%	1.7%	3.3%	3.3%	3.6%
<b>Total Change</b>	<b>2.9%</b>	<b>0.7%</b>	<b>1.6%</b>	<b>1.6%</b>	<b>1.8%</b>

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

Under the BAU scenario, Mexico's projected energy supply shows good potential. It is likely the economy will not only remain a large oil producer, but it will also sustain its crude oil exports into the future. Depending on the actual time and size of the development of its unconventional shale gas resources, the economy could also redefine its trade flows in the long term to become a net gas exporter.

In the electricity sector, the economy's target of 35% of its electricity generation to be based on carbon-free technologies by 2026 is not likely to be accomplished by that year, or even within the outlook period. Nonetheless, the projections suggest Mexico's efforts to fight climate change will achieve some success in the electricity sector as its CO<sub>2</sub> emissions are expected to increase at a slower pace than those of the final-demand sectors.

Although successful programs have been implemented in the residential and commercial sectors in recent years, Mexico will need more policies focused on energy efficiency, in particular ones focused on sectors such as transport and industry. In the light of the new government in Mexico and its priorities, the energy sector remains as one of the biggest challenges for improving economy-wide competitiveness and reducing CO<sub>2</sub> emissions.

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the results from the business-as-usual (BAU) scenario, three sets of alternative scenarios were developed for most APEC economies.

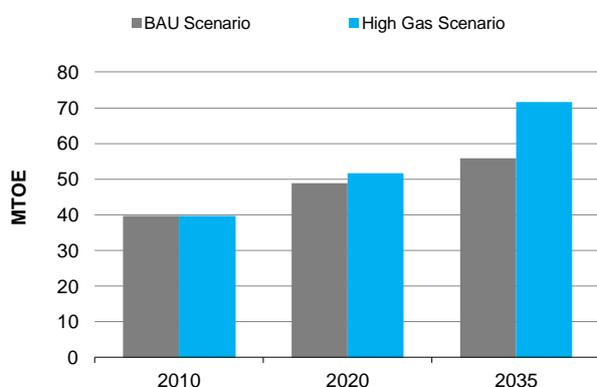
### HIGH GAS SCENARIO

An alternative 'High Gas Scenario' was developed to consider the effects a higher gas output could have on Mexico's energy sector. The High Gas Scenario was built around estimates of gas production that could be available at BAU scenario prices or below if constraints on gas production and trade were reduced. The assumptions of the High Gas Scenario are further discussed in Volume 1, Chapter 12.

As shown in Figure MEX8, the High Gas Scenario for Mexico estimates an increase of 28% in gas production by 2035 in comparison with the BAU scenario. Assumptions of a larger output are based on the greater shale gas production that would result if an additional shale gas play were developed in the long term, as stated in the ENE's optimistic scenario.

Since ENE’s outlook period only extends to 2026, it was assumed that the additional production achieved would be sustained afterwards, up to 2035.

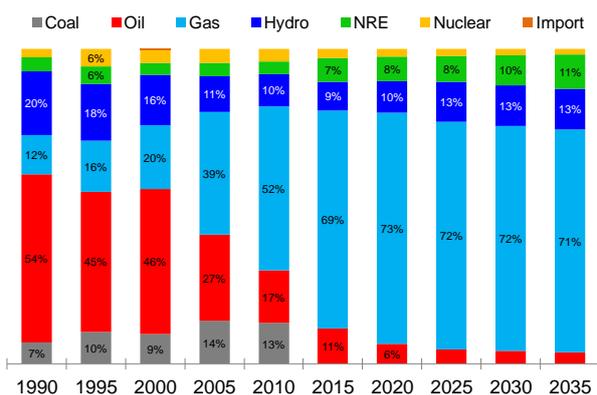
**Figure MEX8: High Gas Scenario – Gas Production**



Source: APERC Analysis (2012)

The High Gas Scenario assumes that the main use for the additional gas will be as a replacement for coal in the electricity generation sector. The effects of higher gas utilization on Mexico’s electricity generation mix are presented in Figure MEX9 and may be contrasted with the BAU electricity generation mix shown in Figure MEX6. It can be seen that, by 2035, gas-based electricity generation will completely replace all coal-based generation and account for 71% of the total electricity generation mix in Mexico. This compares to a projected 55% share under BAU.

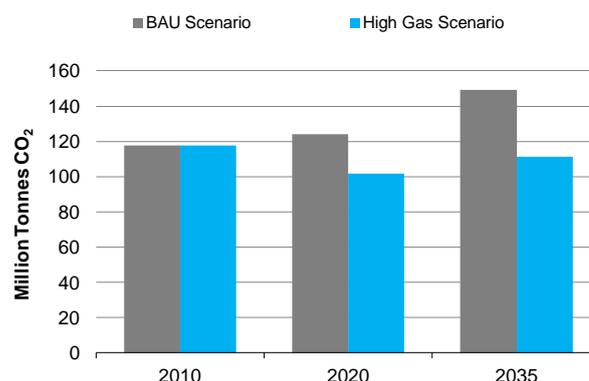
**Figure MEX9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
 Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas produces roughly half of the CO<sub>2</sub> emissions of coal per unit of electricity generated, in Mexico this substitution would reduce CO<sub>2</sub> emissions in electricity generation by 25% in 2035, as depicted in Figure MEX10.

**Figure MEX10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



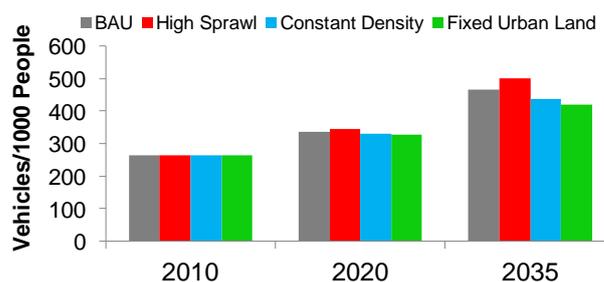
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To better appreciate the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in more detail in Volume 1, Chapter 5.

Figure MEX11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. In comparison to BAU, it is estimated that by 2035 the High Sprawl scenario would expand the number of vehicles per 1000 people by 7%, while in the Constant Density and Fixed Urban Land scenarios, decreases of 6% and 10% respectively are expected.

**Figure MEX11: Urban Development Scenarios – Vehicle Ownership**

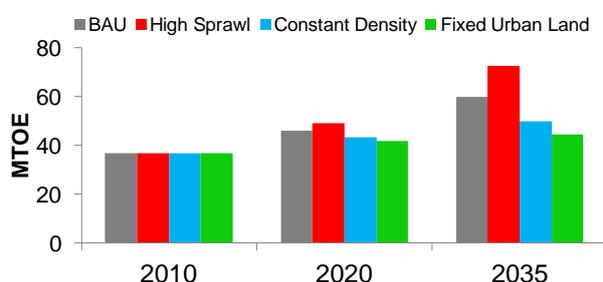


Source: APERC Analysis (2012)

Figure MEX12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of these scenarios on oil consumption is larger than it is on vehicle ownership. In comparison to BAU, it is estimated that by 2035 the High Sprawl scenario would expand the light vehicle oil consumption by 21%, while in the Constant Density and Fixed Urban

Land scenarios, decreases of 16% and 26% respectively, are expected.

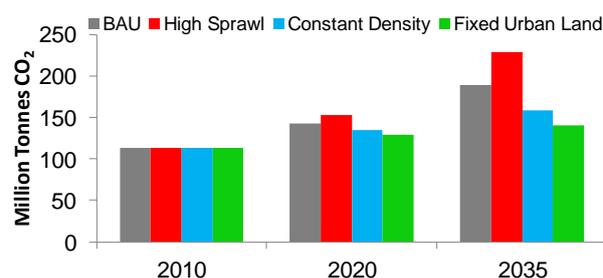
**Figure MEX12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure MEX13 shows the impact of these urban planning alternatives on CO<sub>2</sub> emissions, which is similar to the impact of the urban planning alternatives on oil consumption, as there is no significant change in the mix of fuels used in any of these scenarios.

**Figure MEX13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



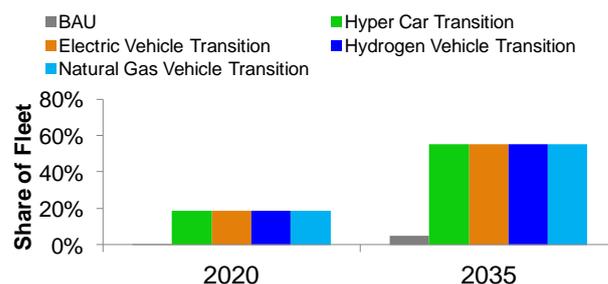
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To assess the possible impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The main assumptions behind these scenarios are discussed in more detail in Volume 1, Chapter 5.

Figure MEX14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of the alternative vehicles in the fleet would reach 55% compared to about 5% in the BAU scenario. Therefore, the share of conventional vehicles in the fleet under the alternative scenarios decreases to 45% in contrast to the 95% share projected for the BAU scenario.

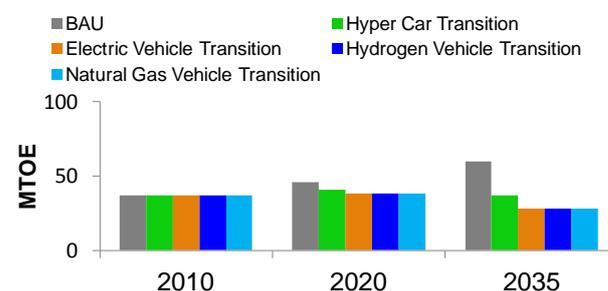
**Figure MEX14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

In Figure MEX15, the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios is presented. Oil consumption drops by 53% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 38% by 2035—even though these highly-efficient vehicles still use oil.

**Figure MEX15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

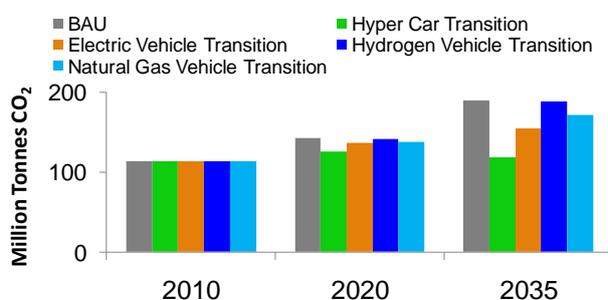
Finally, Figure MEX16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, the change in CO<sub>2</sub> emissions in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios is defined as the variations in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different emission factor per unit of energy.

In comparison to BAU, the results suggest the Hyper Car Transition scenario is the best option for Mexico in terms of reducing CO<sub>2</sub> emissions, with a 37% decrease by 2035. The Electric Vehicle Transition scenario would be second, offering a reduction of 18%, while the Natural Gas Vehicle

Transition scenario would offer a reduction of 10%. Although electric vehicles produce no CO<sub>2</sub> directly, the electricity consumed is assumed to be produced from fossil fuels, limiting their emissions reduction potential. Natural gas is, of course, a fossil fuel whose combustion emits CO<sub>2</sub>, although in modestly lower quantities than oil.

The Hydrogen Vehicle Transition scenario offers little CO<sub>2</sub> emissions reduction benefits, emissions are unchanged compared to BAU in 2035. Like electric vehicles, hydrogen vehicles produce no CO<sub>2</sub> directly, however, the hydrogen consumed is assumed to be produced from fossil fuels, with a second transformation of hydrogen to electricity taking place in the vehicle. The conversion losses involved in these two transformation processes negate the emissions reduction potential of hydrogen vehicles.

**Figure MEX16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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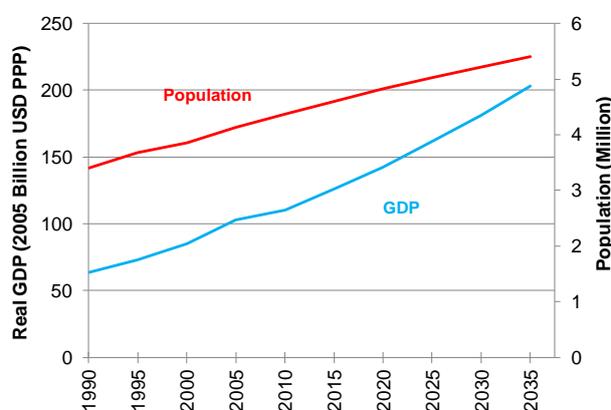
# NEW ZEALAND

- *New Zealand policies aggressively promote energy efficiency; as a consequence, New Zealand's energy demand is likely to grow slowly if at all over the 2010–2035 time period.*
- *New Zealand's gas market is totally isolated, with no pipeline connections or LNG terminals; consequently, the level of future gas discoveries poses major uncertainties for New Zealand's energy outlook*
- *While annual CO<sub>2</sub> emissions from fuel combustion are projected to remain stable at around 35 million tonnes over the 2010–2035 time period, emissions per capita of about 8 tonnes/person in 2010 are still higher than some other wealthy economies and higher than the levels required worldwide to avoid damaging climate change.*

## ECONOMY

New Zealand is an island economy in the South Pacific, consisting of two main islands—the North Island and the South Island—and a number of smaller outer islands. In land area it is a bit smaller than Japan or the Philippines, but larger than the United Kingdom. The relatively small population of about 4.3 million in 2010 is, however, comparable only to a medium-size Asian city. New Zealand's location is remote from other major economies. There are no electricity or pipeline connections to other economies.

Figure NZ1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

New Zealand is a mature economy, whose population is expected to increase only modestly to about 5.4 million by 2035. About 86% of this population is urban, with the Auckland region alone accounting for about one-third of the 2009 population (United Nations, 2009).

Economic growth will be similarly modest, with GDP increasing by an average of about 2.5% per year in real dollars between 2010 and 2035. New Zealand's per capita GDP of about USD 25 000 puts it at the low-end of the OECD economies. However, New Zealand generally rates high in most 'quality of life' surveys. New Zealanders are generally very environmentally conscious, and take pride in the

'clean and green' condition of their land, water, and air.

Most of New Zealand is hilly or mountainous. The climate is mostly cool and wet. Winters are generally not extreme, with snow and ice unusual except in the far south and at higher elevations. However, winter heating of buildings is still necessary and almost universal. Summer cooling of buildings is, however, less common, and mostly limited to large commercial structures. New Zealand is geologically prone to earthquakes, tsunamis, and volcanic eruptions; several earthquakes in 2010 and 2011 caused fatalities and major damage in the Canterbury/Christchurch area.

New Zealand's economy is heavily dependent on agriculture and associated food processing. Major agricultural activities include the raising of dairy cattle, sheep, and other grazing livestock, as well as the cultivation of orchards and vineyards. Other major export industries include tourism, fishing, coal mining, forestry, and forest products processing.

Because its climate is ideal for pastures, New Zealand is the world's largest dairy exporter, and has been described as the 'Saudi Arabia of Milk' (Wall Street Journal, 2008). The dairy processing industry is particularly energy intensive, as much of New Zealand's dairy exports must be dried or condensed.

Another energy-intensive export industry is the aluminium smelter located at Bluff, which accounts for about 12% of New Zealand's electricity consumption (Covec, et al., 2006). New Zealand has two plants that convert natural gas into methanol, mostly for export. These methanol plants are currently only partially utilized, and their future operation will depend upon the availability of gas and the spread between local gas prices and international methanol prices. There is also one integrated steel mill, one oil refinery, and one chemical plant that converts natural gas into urea (mostly for fertilizer), all of which serve mostly domestic markets.

Although Auckland and Wellington have small commuter rail systems, and all cities have local bus services, the automobile is the dominant mode of local passenger transportation. The automobile and air travel dominate the intercity passenger market, although there are some intercity bus services. Intercity rail services are limited to three routes, mostly served only once a day in each direction. New Zealand has only a few short motorways. Highways and local roads are well maintained, but often narrow and twisty. All of this is unlikely to change very much by 2035 under current policies.

Domestic freight transport is also dominated by road transport, although the railways (re-acquired by the government in 2008) have a role, especially in moving container freight, coal, and other commodities. Due to New Zealand's remote location, New Zealand is heavily dependent on overseas air and ship transport for both freight and tourism.

The majority of New Zealand's automobile fleet is imported used from Japan. There is no domestic automobile manufacturing industry.

## ENERGY RESOURCES AND INFRASTRUCTURE

Although New Zealand has a modest oil and gas producing industry, New Zealand was 63% dependent on imports of oil and oil products in 2009. New Zealand also produces a significant quantity of natural gas, which is used for electricity generation, directly in homes and businesses, and in the methanol and urea plants mentioned above. However, only the North Island has a natural gas pipeline and distribution network. New Zealand's gas market is totally isolated from the rest of the world, as there are no facilities for importing natural gas on either island. All of New Zealand's gas is currently domestically produced.

New Zealand's gas and domestic oil come primarily from the Taranaki Basin, where there are several offshore fields. The largest of these fields, Maui, is in depletion, and there has been concern that New Zealand's gas supply could be inadequate in future years. Proposals have been made to build a liquefied natural gas (LNG) terminal to allow the importation of LNG. However, private investors have not been willing to finance such a major investment without government backing, and the government thus far has not been willing to provide the necessary support.

Despite the immediate concerns about gas supply, New Zealand's long-term prospects for finding more domestic gas, and oil as well, are excellent. To quote the website of New Zealand

Petroleum & Minerals, the agency that manages New Zealand's oil and gas resources:

“Taranaki Basin, covering an area of about 330,000 km<sup>2</sup>, is currently the only producing basin in New Zealand. ... The basin remains under-explored compared to many comparable rift complex basins of its size and there remains considerable potential for further discoveries.

The rest of New Zealand is severely under-explored. Nevertheless, frontier basins drilled to date have all yielded discoveries confirming viable petroleum systems. Given many untested structures mapped have closures bigger than the Maui field (New Zealand's largest field), there is considerable potential for commercial hydrocarbon discoveries under New Zealand's largely untouched seabed.” (NZP&M, 2012)

The last few years have indeed seen a series of small discoveries in the Taranaki Basin.

Why the lack of exploration? First, oil is the big prize that most exploration firms seek, and New Zealand's geology is widely viewed as gas-prone. Indeed, much of New Zealand's current ‘oil’ production is actually natural gas liquids. Second, New Zealand's gas infrastructure is underdeveloped. A modest discovery outside the Taranaki Basin would require the construction of a gas pipeline system to reach the New Zealand market. A really major gas discovery would swamp the New Zealand market and require the construction of an LNG export facility. Either way, the cost of the investment would reduce the value of the gas at the wellhead. Third, many of the best potential drilling sites are distant from shore, in deep water, and exposed to severe sea conditions, making drilling difficult and expensive (Samuelson, 2008). However, each of these barriers is likely to be overcome as technology improves and oil prices rise.

With historically abundant hydro resources, New Zealand is heavily dependent on electricity. Many homes and businesses in New Zealand have electric space heating and electric water heating. About 55% of New Zealand's electricity is generated by hydro. However, the best sites for hydro plants have been largely developed, and there is strong environmental opposition to developing the remaining sites. While some small additional hydro projects may be possible, major new hydro projects are unlikely. New Zealand's heavy dependence on hydro for electricity generation leaves its electricity supplies subject to fluctuations in precipitation. Dry years in New Zealand have historically resulted in electricity supply crises.

New Zealand has only one major coal electricity generation plant, Huntly, commissioned in 1987 (NZMED, 2012, Table G3.C). While there is only one coal plant, it operates as a baseload facility and accounted for about 8% of New Zealand's electricity production in 2009. Although New Zealand has significant domestic coal resources, there is strong opposition to new coal plants because of their greenhouse gas emissions. Although Huntly will probably continue to operate for some time, it is unlikely that a new coal plant could be built in New Zealand without carbon capture and storage.

Gas accounted for about 21% of New Zealand's electricity production in 2009. While there is environmental opposition to new gas plants on the basis of their greenhouse gas emissions, the opposition is less strong than it would be for coal. Gas has the advantages of a relatively low capital cost, a short construction and approval cycle, and an ability to avoid transmission constraints (since gas plants can be built close to major markets and existing transmission infrastructure). So gas is an attractive option for new electricity generation.

Geothermal electricity accounted for about 13% of New Zealand's electricity production in 2009, and there is significant potential for more. It is worth noting that, in accordance with New Zealand's statistical standards, we assume geothermal energy has a conversion efficiency of only 15%. This means it takes roughly seven units of primary geothermal steam energy to produce one unit of electricity. As a result, our figures for primary energy from new renewable energy (NRE) for New Zealand are quite large, perhaps deceptively so.

Wind power, which currently accounts for about 4% of New Zealand's electricity production in 2009, could also be expanded significantly. Unlike most economies, New Zealand's windy climate often allows wind farms to be developed without subsidy.

New Zealand has only one small oil-fired generation plant, which serves as a reserve resource. Due to high costs and concerns about the security of supply, oil is probably New Zealand's least-preferred option for electricity generation.

## ENERGY POLICIES

New Zealand has adopted an economy-wide target for a 50% reduction in New Zealand's carbon-equivalent net emissions, compared with 1990 levels, by 2050. New Zealand is willing to commit to reducing greenhouse gas emissions by between 10% and 20% below 1990 levels by 2020, if there is a comprehensive global agreement and certain conditions are met (NZMED, 2011).

The Climate Change Response (Emissions Trading) Amendment Act 2008 established New Zealand's emissions trading scheme. The scheme places a price on greenhouse gas emissions to provide an incentive to reduce the volume of overall emissions. Six gases covered under the Kyoto Protocol are covered under the scheme—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (CCINZ, 2011).

In August 2011, the government released the *New Zealand Energy Strategy 2011–2021: Developing Our Energy Potential* (NZMED, 2011) to replace the 2007 New Zealand Energy Strategy. The new strategy focuses on four priorities: diverse resource development; environmental responsibility; the efficient use of energy; and secure and affordable energy. As part of the Energy Strategy, the New Zealand Government retains the target of 90% of electricity to be generated from renewable sources by 2025, provided security of supply is maintained.

New Zealand has a relatively long tradition of promoting energy efficiency, having passed an Energy Efficiency and Conservation Act in the year 2000, which led to the first National Energy Efficiency and Conservation Strategy, as well as the establishment of the Energy Efficiency and Conservation Authority (EECA) to spearhead the implementation of the strategy. The Energy Strategy includes a revised New Zealand Energy Efficiency and Conservation Strategy 2011–2016. The overall goal of the new strategy is for New Zealand to continue to improve its energy intensity (energy used per unit of GDP) by 1.3% per year to 2016. New Zealand has no fossil fuel subsidies that would encourage wasteful consumption.

New Zealand's oil and gas exploration and production activities are largely in private ownership and open to competition. New Zealand generally welcomes investments in oil and gas exploration by foreign firms. Electricity generation and marketing is also largely open to competition, but three of the five major generators are state-owned firms, as is the transmission grid operator. The New Zealand Electricity Authority oversees the rules of the electricity market, but does not regulate electricity prices.

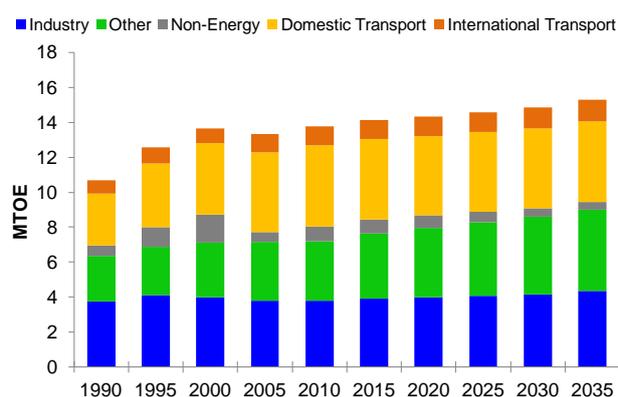
The coal mining industry in New Zealand is dominated by a large state-owned firm, although there are private operators as well.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at 0.4% per year over the outlook period. The ‘other’ sector (covering residential, commercial, and agriculture uses) will account for 91% of the growth. Demand is more or less evenly split between industry, transport and ‘other’. Final energy intensity is expected to decline by about 42% between 2005 and 2035.

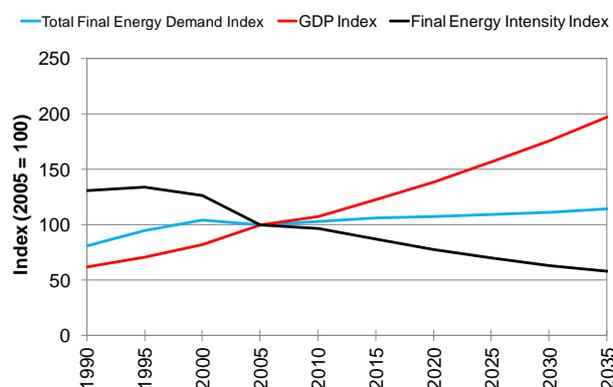
Figure NZ2: BAU Final Energy Demand



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011a

Figure NZ3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.5% until 2035, reflecting the slow growth of New Zealand industry generally. New Zealand’s heavy industry is dominated by a few big firms. The aluminium and chemical industries may be viewed as a way of exporting surplus energy. Their future will depend on the availability of low-cost electricity and gas respectively. The other industries have competitive advantages in their local or export markets, so their demand is expected to be stable.

Some growth in light industry is expected, but it is unlikely to be energy intensive.

Industrial electricity use is projected to increase from 1.2 Mtoe in 2010 to 1.5 Mtoe in 2035, accounting for the fastest growth, both in absolute industrial energy demand and in percentage terms, at an average annual rate of 0.8%.

### Transport

Vehicle ownership in New Zealand has already reached saturation level. Over the outlook period, the domestic transportation energy demand of New Zealand is projected to remain almost unchanged. Rising vehicle kilometres travelled will be offset by increasingly efficient vehicles. Higher vehicle fuel efficiency will be stimulated by stricter fuel efficiency standards in Japan, from which the majority of New Zealand’s vehicles are imported in used form, as well as by New Zealand’s own vehicle efficiency labelling scheme.

Although New Zealand currently exempts electric vehicles from road user charges, almost all transport energy demand is likely to be for oil products. Conventional diesel vehicles will be increasingly common, comprising about one-quarter of the light vehicle fleet by 2035.

### Other

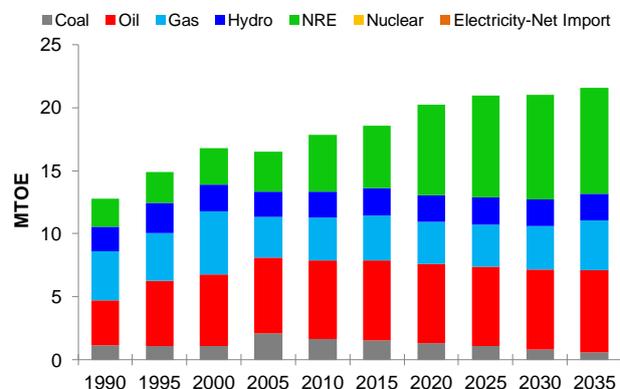
New Zealand’s energy efficiency building codes, minimum efficiency performance standards for appliances, and assistance for home insulation and clean heating retrofits will help to hold down the growth of residential energy demand.

However, these efforts will be offset by a growing population, larger homes, and more appliances. Energy demand in the ‘other’ sector, which includes residential, commercial, agricultural and construction demand, is expected to grow at 1.3% per year over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for 62% of ‘other’ energy consumption in 2035.

### PRIMARY ENERGY SUPPLY

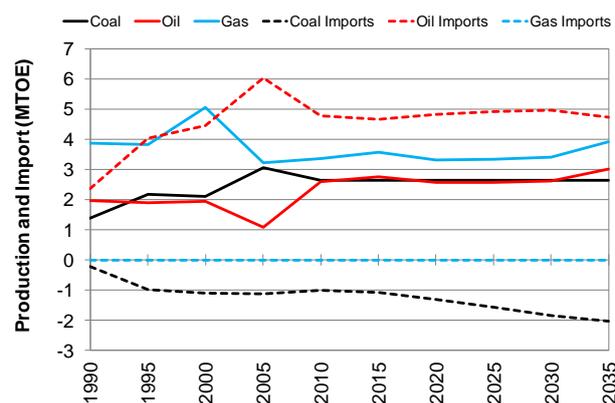
New Zealand’s primary energy supply in the 2010–2035 period is projected to grow at an annual rate of 0.8%.

Figure NZ4: BAU Primary Energy Supply



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011a

Figure NZ5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011a

Given the isolated nature of New Zealand’s gas market, the amount of gas that will be available is perhaps the greatest uncertainty in New Zealand’s energy outlook. In APERC’s view, the evidence suggests that additional gas supplies are likely to be found. As noted above, the geological prospects are good. And the market seems to be responding, with exploration and development activity continuing at historically high levels. New Zealand’s Energy Data File 2012 notes that NZD 6.8 billion has been spent in the most recent five years (2007–2011) on oil and gas exploration and development. By comparison, from 2002 to 2006 a total of NZD 2.7 billion had been spent (NZMED, 2012, Table H.1).

The availability of gas is likely to allow New Zealand to continue to generate electricity from gas, and to meet any gap between electricity demand

growth and new renewable energy (NRE) generation with domestic gas. It is also likely New Zealand can continue to produce methanol for export from gas.

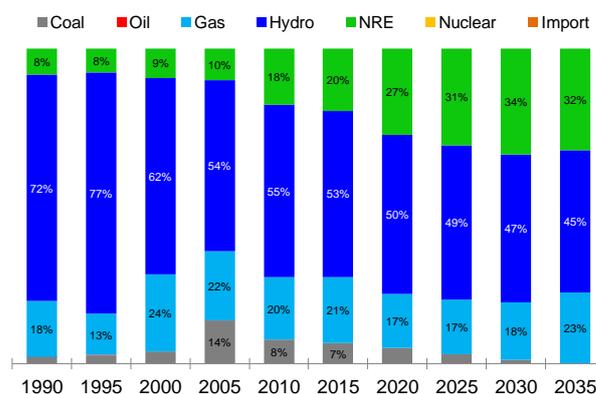
Oil production is subject to similar uncertainties and similar good prospects. Given New Zealand’s very small projected increase in oil demand to 2035, any increase in oil production could reduce New Zealand’s dependence on oil imports. APERC projects a very slight decline in oil imports from about 4.8 Mtoe in 2010 to about 4.7 Mtoe in 2035, but these are highly uncertain figures.

### ELECTRICITY

The availability of gas and renewables should make it possible to gradually phase out New Zealand’s only coal-fired generation plant, Huntly. Electricity production from hydro is likely to remain fairly constant, given the lack of attractive sites for new projects and the opposition to hydro development at the sites that are available. However, other forms of renewable generation, including wind and geothermal, are likely to more than double between 2010 and 2035, reflecting both available resources and existing supportive government policies.

Given the many uncertainties, especially regarding gas discoveries, it is difficult to say if New Zealand will reach its goal of 90% renewable electricity by 2025. Given the isolated nature of the New Zealand gas market, if significant amounts of additional gas are discovered, as APERC assumes, it will probably be priced to be competitive with renewables in the electricity generation market, since it has nowhere else to go.

Figure NZ6: BAU Electricity Generation Mix

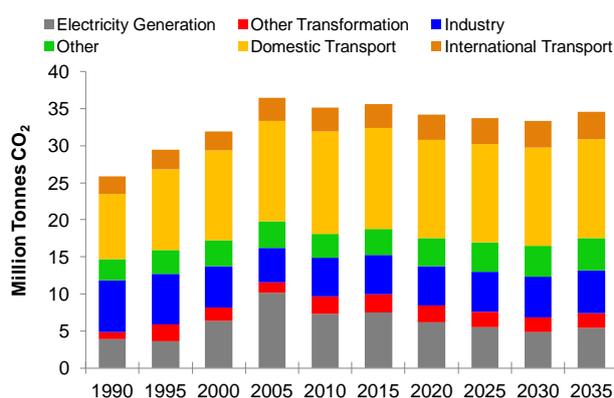


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011a

## CO<sub>2</sub> EMISSIONS

Over the outlook period New Zealand's total CO<sub>2</sub> emissions from fuel combustion are projected to remain approximately stable at around 35 million tonnes. This result is explained by the stable use of oil in the transport sector, the declining use of coal in electricity generation offset by a modest increase in the use of gas, the stable demand for fossil fuels in the industrial sector, and only a small increase in demand in the residential/commercial/agricultural ('other') sector.

Figure NZ7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table NZ1 below suggests the growth in New Zealand's GDP will be offset by a small reduction in the CO<sub>2</sub> intensity of energy (fuel switching) and a small reduction in the energy intensity of GDP (energy efficiency).

It should be noted that New Zealand is unusual among developed economies in that total greenhouse gas emissions from agriculture have historically slightly exceeded emissions from energy (NZMFE, 2011).

Table NZ1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.6%	-2.3%	-1.3%	-1.0%	-0.8%
Change in Energy Intensity of GDP	-1.5%	0.1%	-1.3%	-1.4%	-1.7%
Change in GDP	3.3%	1.4%	2.3%	2.3%	2.5%
Total Change	2.3%	-0.8%	-0.4%	-0.2%	-0.1%

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

By comparison with most economies, New Zealand's business-as-usual energy outlook is reasonably good. CO<sub>2</sub> emissions from fossil fuels may be stable over the 2010–2035 time period, while oil imports may decline. However, at around 8 tonnes/person each year, New Zealand's CO<sub>2</sub>

emissions per person from fossil fuel consumption remain relatively high on a world scale, higher for example than the 2009 emissions of France, Sweden, or Switzerland (IEA, 2011b, p. 97), and far above the level which must be achieved worldwide to avert damaging climate change (see Volume I, Chapter 16).

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

### HIGH GAS SCENARIO

To understand the impacts that higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

New Zealand's gas market is, however, a rather exceptional case for two reasons. First, with no pipeline connections to other economies, and no LNG terminals, New Zealand's gas market is totally isolated from other economies. Second, while an increase in New Zealand's gas production beyond BAU levels is a definite possibility, it would probably cause New Zealand's CO<sub>2</sub> emissions to increase rather than decrease. This is because, in APERC's BAU scenario, the only major coal-fired electricity generation plant will be phased out. So rather than competing with coal, gas competes primarily with renewables including wind and geothermal.

So, unlike other APEC economies, increased gas production in New Zealand would likely have negative, rather than positive, environmental impacts. The only exception would be if the increase in New Zealand's gas production were so huge that it made the construction of an LNG export terminal economic. In this event, New Zealand could export gas to other APEC economies where it could be used to replace coal. Given the underexplored nature of much of New Zealand's territory, large future gas discoveries are a possibility. However, the currently known gas resources in New Zealand would not allow for LNG exports at the present time.

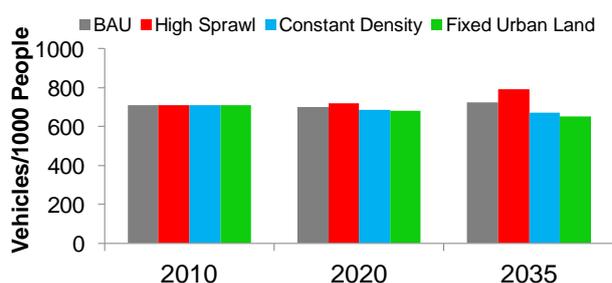
For these reasons, the High Gas Scenario was not run for New Zealand. Figures NZ8–NZ10 are, therefore, not included here.

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure NZ11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 10% lower in the Fixed Urban Land scenario. Given that New Zealand is a relatively wealthy economy with vehicle ownership at close to saturation levels, the model results suggest better urban planning could modestly reduce the need for people to own vehicles. New Zealand’s cities, especially Auckland, are currently characterized by a high level of ‘sprawl’.

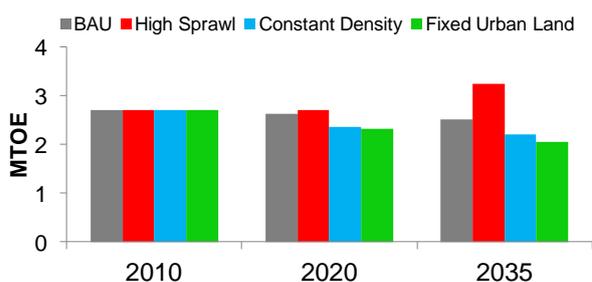
**Figure NZ11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure NZ12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is more pronounced than on vehicle ownership, as more compact cities reduce both the need for vehicles and the distances they must travel.

**Figure NZ12: Urban Development Scenarios – Light Vehicle Oil Consumption**

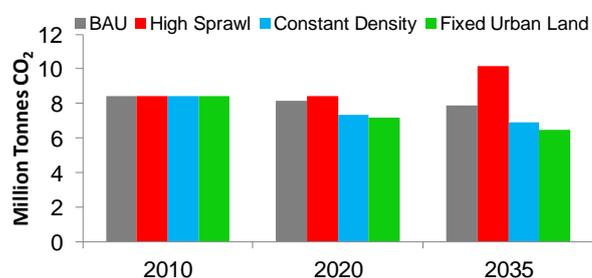


Source: APERC Analysis (2012)

Light vehicle oil consumption would be 29% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 18% lower in the Fixed Urban Land scenario.

Figure NZ13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO<sub>2</sub> emissions would be 29% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 18% lower in the Fixed Urban Land scenario.

**Figure NZ13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



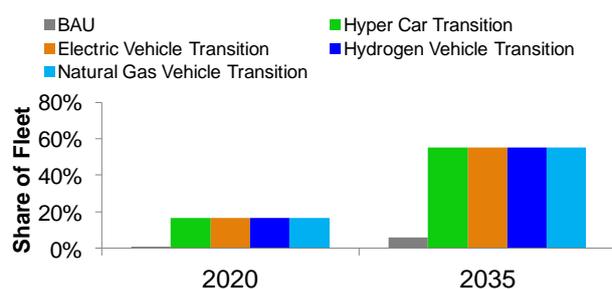
Source: APERC Analysis (2012)

### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure NZ14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035, the share of the alternative vehicles in the vehicle fleet is assumed to reach about 55% compared to about 6% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 45%, compared to about 94% in the BAU scenario.

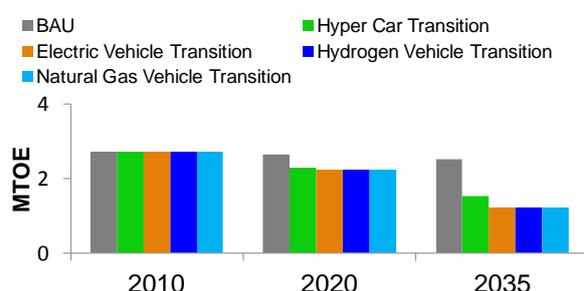
**Figure NZ14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure NZ15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—40% by 2035—even though these highly-efficient vehicles still use oil.

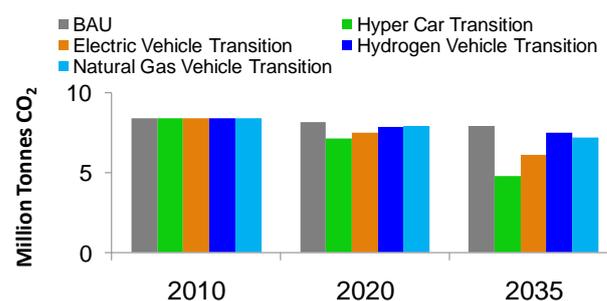
**Figure NZ15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure NZ16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition Scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure NZ16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In New Zealand, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reductions with emissions reduced 39% compared to BAU in 2035. This figure is roughly in line with their reduction in oil demand. The Electric Vehicle Transition scenario comes in second, offering a 22% reduction. Electric vehicles offer a significant reduction because in New Zealand the additional electricity for electric vehicles would be generated with gas rather than the coal that would be used in many APEC economies (to facilitate fair comparisons, the Electric Vehicle Transition scenario assumes no additional renewable generating capacity). The Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer considerably less emissions reductions (9% and 5%, respectively).

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# PAPUA NEW GUINEA

- Papua New Guinea will become a major LNG exporter with the start-up of LNG export projects after 2014.
- Papua New Guinea's total primary energy supply is projected to increase from 2.2 Mtoe in 2010 to 6.7 Mtoe in 2035; fuel gas for LNG liquefaction accounts for a significant portion of this increase.
- Papua New Guinea may shift from a net oil exporter to a net oil importer after 2020 unless new reserves of oil are found.
- Papua New Guinea has a significant hydroelectric and geothermal potential. The government plans to either build or upgrade 800 MW of hydro electricity and over 500 MW of geothermal generating capacity within the next 10–15 years to provide a reliable and affordable electricity supply.

## ECONOMY

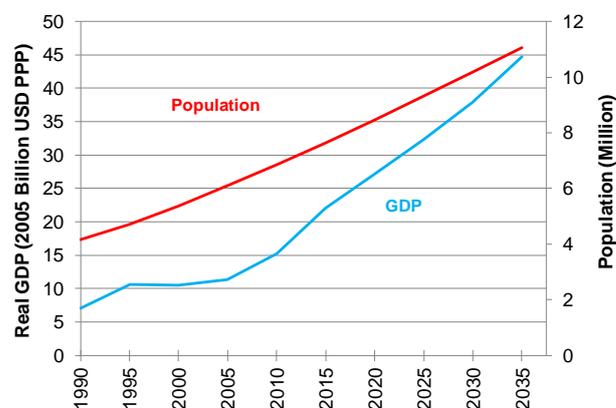
Papua New Guinea is located in the south-western Pacific Ocean, just south of the equator. It is made up of over 600 islands, including the eastern half of New Guinea—the world's second-largest island—as well as the Bismarck Archipelago, the D'Entrecasteaux island group, and the three islands of the Lousiade Archipelago. New Guinea and the larger islands are mountainous and rugged, with a string of active volcanoes dotting the north part of the mainland and continuing to the island of New Britain.

Papua New Guinea's population was 6.7 million in 2009, with more than 80% living in rural areas. Most of the rural population are dependent on subsistence farming. Only 13% of households have access to electricity (DNPM, 2010a).

The population is expected to grow at an average annual rate of 1.9% over the outlook period. The population in Papua New Guinea's major cities and towns is expected to double by 2035, to reach 2 million people as a result of the high rural-urban migration to the National Capital District and other major towns like Madang, Mt Hagen, Lae, Kimbe and Rubail. Rural provinces such as Chimbu, East Sepik, Milne Bay, Oro, Gulf and Munus are expected to experience an out-migration of people as a result of a lack of services and income opportunities.

Papua New Guinea has achieved moderate economic growth and government surpluses since 2003. Economic growth has primarily been aided by high commodity prices. The real GDP growth rate between 2005 and 2010 was 6%. GDP is expected to continue to expand at an average annual rate of 4.4% over the outlook period.

Figure PNG1: GDP and Population



Sources: USDA ERS (2012) and APERC Analysis (2012)

The economy of Papua New Guinea can be separated into subsistence non-market and market sectors. The market economy is dominated by large-scale resource projects, particularly mining, oil and gas. Agriculture currently accounts for 13% of GDP and supports more than 75% of the population (DNPM, 2010a). The economy's primary cash crops are coffee, palm oil, cocoa, copra, tea, rubber and sugar. Some of the rural population are involved in smallholder cash cropping of coffee, cocoa and copra. Operations in Papua New Guinea's mining, timber, and fishing sectors are largely foreign owned.

Papua New Guinea is endowed with substantial mineral resources, including gold, copper and natural gas. Government revenue depends heavily on minerals exports and after 2014 it will benefit from the start of liquefied natural gas (LNG) exports. The remainder of Papua New Guinea's industry sector is made up of light industries and agricultural processing industries.

Papua New Guinea's economic development will require considerable growth in the coverage and quality of its state transport network. Currently, Papua New Guinea has one of the lowest road densities in the world. The total road network is

30 000 kilometres (km), of which 8460 km are state roads. Only 28% of the 8460 km of state roads were in a good condition in 2010. A comprehensive program of rehabilitating existing roads and constructing new roads would expand the state road network to 25 000 km by 2035 (DNPM, 2010a, p. 66). Congestion on roads in the urban areas will be a growing issue as the number of passenger vehicles is expected to increase rapidly with rising income levels.

About 60% of Papua New Guinea's population depends on water transportation including for the delivery of goods and services. The water transport system's services and infrastructure will also require upgrading. Port Moresby, Lae and Kimbe are the economy's busiest seaports, accounting for more than 80% of its cargo. Between 2010 and 2035 it is projected the cargo throughput at all Papua New Guinea's ports will increase five-fold under rapid development (DNPM, 2010a).

The aviation industry will continue to play a vital role. For many remote parts of Papua New Guinea, air transport is their only possible link with the main centres. However, the economy's regional airports do not meet international standards and need to be developed to handle larger planes and increased passenger numbers.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

The Papuan Basin in the south-eastern part of Papua New Guinea is the most explored and developed oil and gas region in the economy—particularly the Papuan Fold Belt and Papuan Foreland areas. There has also been exploration in the North New Guinea basin, and the Cape Vogel, New Ireland and Bougainville basins.

Papua New Guinea's proven hydrocarbon reserves consist primarily of natural gas (440 billion cubic metres (bcm)), followed by oil (0.660 billion barrels) and gas condensates (0.262 billion barrels). The inclusion of inferred, mean-risk reserves would increase oil reserves by an additional 1 billion barrels, and natural gas by more than 283 bcm (PNG CMP, 2012).

Oil development started in 1991 with crude oil production at the Kutubu fields. Production at the Kutubu fields peaked in 1993, but has been declining. The fields are projected to be depleted by 2026 (DNPM, 2010a).

In 2005, Papua New Guinea's first oil refinery started production, sourcing crude oil from both local oil fields and imports. In 2008, 5.8 million

barrels of crude oil were processed (DNPM, 2010a). The capacity of the existing refinery, with expansion, could reach 9 million barrels by 2035.

Papua New Guinea's ExxonMobil-led LNG export project is expected to start up in 2014, with a capacity of 6.6 million tonnes per year. Consideration is being given to adding a third train (ExxonMobil, 2010). InterOil has obtained government approval for its plans to develop another LNG project at Elk-Antelope with construction starting after 2014. Its project would be similar in size to the ExxonMobil-led LNG export project (Platts, 2012). The project's final investment decision should be reached in 2013. These projects can greatly stimulate Papua New Guinea's economy. In general, Papua New Guinea is considered to be underexplored for gas.

Papua New Guinea has a significant hydroelectric potential. Its land area includes nine large hydrological drainage divisions (basins). The largest river basins are the Sepik (catchment area of 78 000 square kilometres (sq km)), the Fly (61 000 sq km), the Purari (33 670 sq km), and the Markham (12 000 sq km). There are other catchments of less than 5000 sq km, in areas that are very steep. On the mainland, the mean annual rainfall ranges from less than 2000 mm to 8000 mm in some mountainous areas, while the island groups receive a mean annual rainfall of 3000–7000 mm. The gross theoretical hydropower potential for Papua New Guinea is 175 terawatt-hours (TWh) per year (Encyclopedia of Earth, 2008). By 2035, 800 MW of hydro electricity generating capacity is planned to be either built or upgraded (DNPM, 2010a).

The Geothermal Energy Association estimates Papua New Guinea's geothermal potential at 21.92 TWh. The association also categorizes Papua New Guinea as an economy that could, in theory, meet all its power needs from geothermal sources alone, well into the future (GEA, 2010).

The government in partnership with the private sector will pursue the development of renewable sources, including geothermal. By 2035, about 500 MW of new geothermal electricity generating capacity could be put into operation in the economy (DNPM, 2010a).

Papua New Guinea has three large regional electricity power grids. The Port Moresby system serves the National Capital District and surrounding areas in the Central Province. The main source of generation is the Rouna system consisting of four hydro stations on the Laloki River, controlled water storage in the Sirinumu Reservoir, and a small generator at the toe of the Sirinumu dam. The total generation capacity from the Rouna power stations is

62.2 MW. A thermal power station at Moitaka, outside Port Moresby, has a generation capacity of 30 MW based on diesel and gas turbines. A privately-owned diesel power station at Kanudi has a capacity of 24 MW (JOGMEC, 2011).

The Ramu system serves the load centres of Lae, Madang and Gusap in the Momase Region and the Highlands centres of Wabag, Mendi, Mt Hagen, Kundiawa, Goroka, Kainantu and Yonki. The main source of generation is the Ramu Hydro Power Station with an installed capacity of 75 MW, comprising five units of 15 MW each. Additional hydro energy is supplied by Pauanda, a 12 MW run-of-river station in the Western Highlands Province. Power is also purchased when required from the privately owned Baiune Hydro Power Station at Bulolo in the Morobe Province, and varies between 1 MW to 2 MW depending on availability. There are diesel plants at Madang, Lae, Mendi and Wabag. These plants serve as stand-by units.

The Gazelle Peninsula system serves the townships of Rabaul, Kokopo and Keravat and the system is powered by the 10 MW Warangoi hydro plant, the 8.4 MW Ulagunan diesel plant, and the 0.5 MW Kerevat diesel plant (PPL, 2012).

In addition to these three grids there are also oil-based power stations serving various isolated communities.

## ENERGY POLICIES

The Papua New Guinea Government has jurisdiction over energy matters. The Papua New Guinea National Energy Policy and the Rural Electrification Policy are under review by the Government Task Force on Policy. The exploration and development of petroleum resources are authorised and administered by the Department of Petroleum and Energy.

The Papua New Guinea Government has initiated the Papua New Guinea Vision 2050 (NSPT, 2010) which has seven ‘pillars’; natural resources, climate change and environmental sustainability are among the areas of focus. In the Vision 2050, the Papua New Guinea Government notes the economy can make a significant contribution to reducing global greenhouse gas (GHG) emissions with good forest management and through the development of its hydroelectric and geothermal potential.

In its Copenhagen Accord response of 2 February 2010, Papua New Guinea stated it was seeking to “decrease GHG emissions at least 50% before 2030 while becoming carbon neutral before

2050”, subject to certain conditions (UNFCCC, 2010).

In March 2010, the Papua New Guinea Government announced the Development Strategic Plan 2010–2030 (DNPM, 2010a), which has five pillars—one of which is ‘natural resources and environment’.

In October 2010, the Papua New Guinea Government announced its Medium Term Development Plan (MTDP) 2011–2015 (DNPM, 2010b). The MTDP 2011–2015 will focus on increasing access to electricity for all households in the economy. A comprehensive analysis of the cost effectiveness of various alternative sources of power will be required.

Petromin PNG Holdings Limited (Petromin), a state-controlled company, holds the economy’s oil and gas assets and seeks to maximise indigenous ownership and revenue in the petroleum and gas sectors. It will do this through proactive investment strategies either alone or in partnership with resource developers (PNG CMP, 2012).

The state-owned PNG Power Ltd (PPL) is a fully integrated power authority responsible for the generation, transmission, distribution and retailing of electricity throughout Papua New Guinea and for servicing individual electricity consumers.

PPL services customers in almost all urban centres throughout the economy, encompassing the industrial, commercial, government and domestic sectors. The company also has a regulatory role in approving licences for electrical contractors, providing certification for electrical equipment and appliances to be sold in Papua New Guinea, and providing safety advisory services and checks for major installations.

PPL is regulated under a price control mechanism known as the maximum average price (MAP). Under MAP, for each of the tariffs PNG Power Ltd charges to the different classes of its consumers (Industrial, General Supply, Domestic Customers and Public Lighting) the average price of those tariffs must not exceed the MAP determined by the Papua New Guinea Government (PPL, 2012).

The Papua New Guinea Government has been successful in attracting major international oil and gas companies to the economy with its very open oil and gas industry structure.

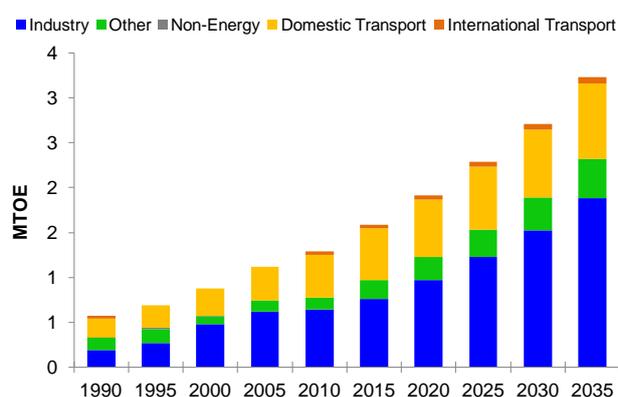
A key strategic objective for the Papua New Guinea Government’s energy policy is to provide access to electricity to at least 70% of households by 2030 (DNPM, 2010a).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at 3.8% per year over the outlook period. The industry sector will account for 59% of final demand in 2035, driven by the development of LNG projects.

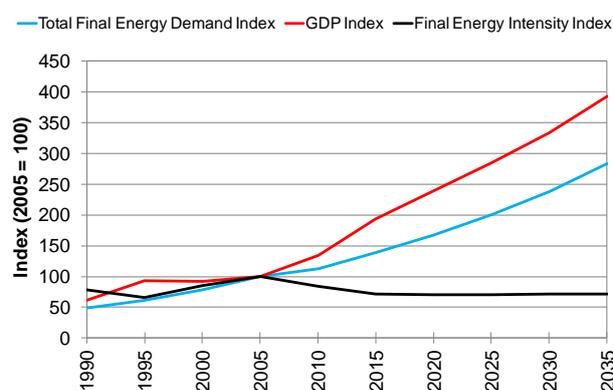
Figure PNG8: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: APEC (2011)

Final energy intensity is expected to decline by about 28% between 2005 and 2035, with the industry, transport and services sectors projected to see a substantial improvement in their energy intensity.

Figure PNG3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

This outlook assumes Papua New Guinea’s industry sector will retain its current structure, which consists mainly of mining, light manufacturing and agricultural processing. However, the scale of production of these industries is expected to grow.

Final industry energy demand is projected to increase at an average annual rate of 4.4%, from 0.6 Mtoe in 2010 to 1.9 Mtoe in 2035.

### Transport

Final energy demand in the transport sector is expected to increase at an average annual rate of 2.3% over the outlook period. This demand will be met almost entirely by oil-derived fuels.

### Other

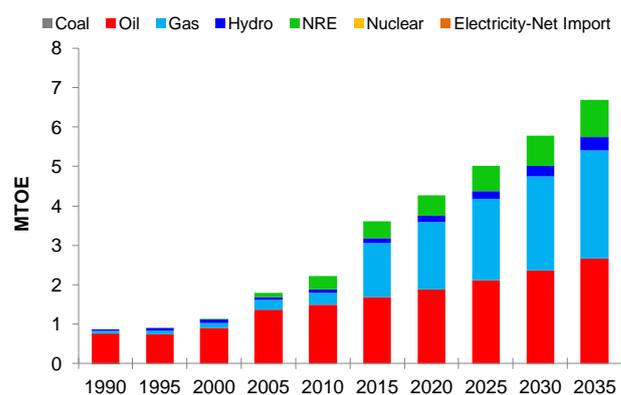
The final energy demand in the ‘other’ sector, which includes residential, commercial and agricultural users, is projected to increase at an average annual rate of 4.8% over the outlook period. In the ‘other’ sector, commercial energy demand will be primarily for electricity, kerosene and LPG (liquefied petroleum gas). There are currently no plans for the construction of a gas distribution network for residential and commercial customers.

The projection for the ‘other’ sector includes only the final demand for commercial energy, due to inadequate information about non-commercial energy use in Papua New Guinea. The economy’s consumption of non-commercial biomass is projected to remain significant over the outlook period.

### PRIMARY ENERGY SUPPLY

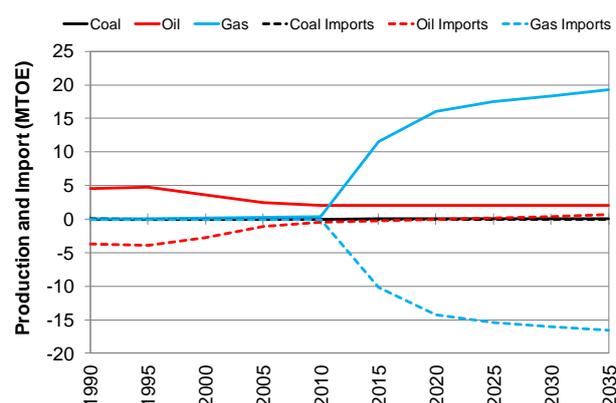
Papua New Guinea’s primary energy supply in the 2010–2035 period is projected to grow at an annual rate of 4.5%. Oil, which was the predominant form of energy before 2010, will be increasingly supplemented with natural gas and new renewable energy (NRE) (mainly geothermal). Papua New Guinea has historically been a modest oil exporter, but could become an oil importer after 2020.

Figure PNG4: BAU Primary Energy Supply



Source: APERC Analysis (2012)  
Historical Data: APEC (2011)

Figure PNG5: BAU Energy Production and Net Imports



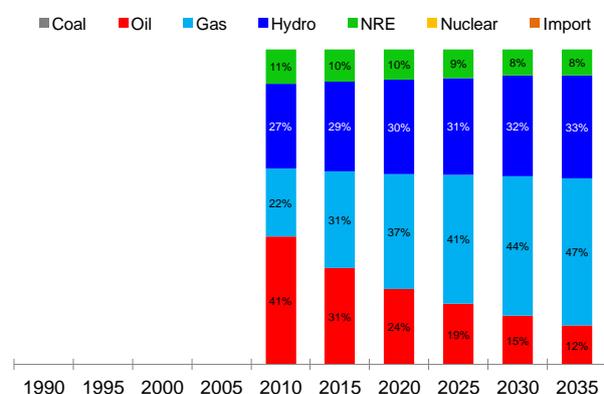
Source: APERC Analysis (2012)  
Historical Data: APEC (2011)

Although not part of final energy demand, about 25% of Papua New Guinea’s primary energy supply in 2035 will be used to produce and liquefy natural gas for export. And, although not part of either primary energy supply or final energy demand, about 86% of Papua New Guinea’s natural gas production will be exported.

**ELECTRICITY**

Electricity generation is projected to grow by 4.9% annually over the outlook period and to reach 12.2 TWh in 2035.

Figure PNG6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical data is not available for Papua New Guinea.

Natural gas electricity generation is expected to increase over 700% between 2010 and 2035 as a result of a natural gas supply becoming available in the Port Moresby area.

Diesel and heavy oil generated electricity have been the main contributors to the high cost structure in the economy’s electricity sector. After 2015, diesel and heavy oil generators will be phased out and retained mainly for back-up purposes.

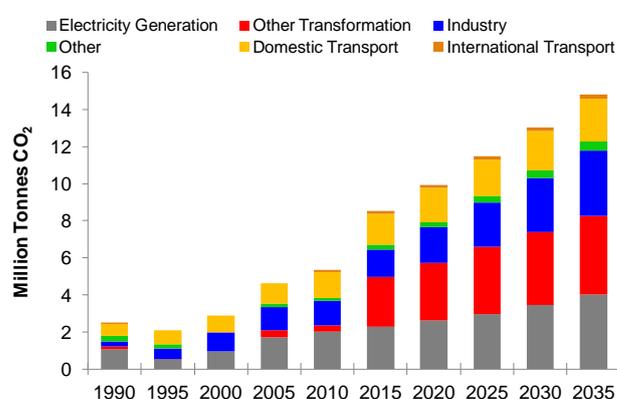
Papua New Guinea has no plans to use coal for power generation.

**CO<sub>2</sub> EMISSIONS**

Papua New Guinea’s CO<sub>2</sub> emissions from the combustion of fuels are projected to reach 14.8 million tonnes in 2035, which is almost a 2.8 times increase from the 2010 level of 5.5 million tonnes.

In 2035, electricity generation and other transformation (primarily own-use in LNG liquefaction plants) are projected to contribute the largest shares of CO<sub>2</sub> emissions (4.0 million and 4.2 million tonnes, respectively), followed by industry (3.6 million tonnes) and transport (2.5 million tonnes).

Figure PNG7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

From the decomposition analysis shown in Table PNG1, it can be seen that economic growth at an annual rate of 4.4% through the outlook period drives the growth in Papua New Guinea’s CO<sub>2</sub> emissions. This will be offset by modest reductions in energy intensity and carbon intensity (in particular, the shift away from oil).

Table PNG1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.8%	-1.1%	-0.7%	-0.6%	-0.5%
Change in Energy Intensity of GDP	1.7%	-1.1%	-0.4%	-0.5%	-0.3%
Change in GDP	3.3%	6.0%	4.9%	4.7%	4.4%
<b>Total Change</b>	<b>4.2%</b>	<b>3.6%</b>	<b>3.9%</b>	<b>3.5%</b>	<b>3.5%</b>

Source: APERC Analysis (2012)

## CHALLENGES AND IMPLICATIONS OF BAU

Given the success of Papua New Guinea's efforts to attract investment in gas exploration and development, the economy should be able to achieve the significant growth in natural gas production we project throughout the outlook period. Our business-as-usual projection, however, shows Papua New Guinea will become a net oil importer before 2035 unless significant new oil reserves are found.

There is a great potential to replace oil in electricity generation. Papua New Guinea is fortunate to have a diversity of lower-carbon options, including the greater use of geothermal and hydropower resources. The development of these resources will have high upfront investment costs. However, they may well be more economic in the long run, compared to the more readily available option of gas-fired electricity generation.

The needs for specialised expertise and considerable financial resources mean Papua New Guinea's development will depend on a transparent, stable, and fair incentive regime for foreign investors.

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies, although only two could be developed for Papua New Guinea.

### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU case prices or below if constraints on gas production and trade could be reduced.

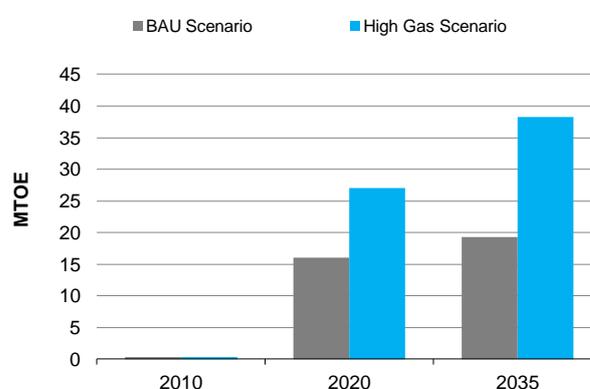
The High Gas Scenario production for Papua New Guinea assumed a production increase almost double the BAU levels, as shown in Figure PNG8. Papua Guinea has the potential for increasing production based on resources which are believed to exist, but this will require significant investment in both production and LNG infrastructure. The High Gas Scenario assumes a continuing transparent, stable, and fair incentive regime for foreign investors, which will enable greater investment in gas production for LNG exports to international markets.

The major impact of this scenario would be to enable Papua New Guinea to increase its LNG

exports to other APEC economies, thereby enabling them to replace more coal with natural gas in electricity generation. Papua New Guinea itself uses no coal in electricity generation, even in the BAU scenario, so we assume no change in the generation mix. Hence Figures PNG9 and PNG10 are not shown.

There may be an additional potential for Papua New Guinea to replace some of the remaining oil used in electricity generation with natural gas. However, oil generation may be needed to serve remote communities where natural gas would not be available. Due to data limitations, this option was not examined.

Figure PNG8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

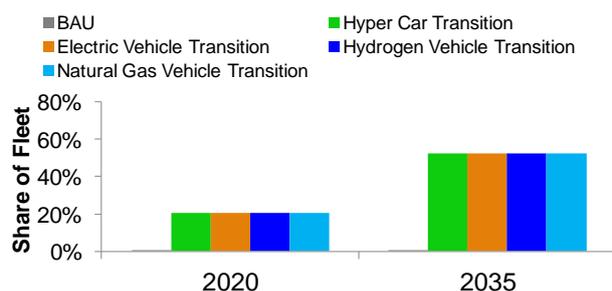
The three alternative urban development scenarios were not examined for Papua New Guinea due to a lack of adequate data. Hence Figures PNG11 to PNG13 are not shown.

### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PNG14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of alternative vehicles in the fleet reaches around 51% compared to about 1% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48%, compared to about 99% in the BAU scenario.

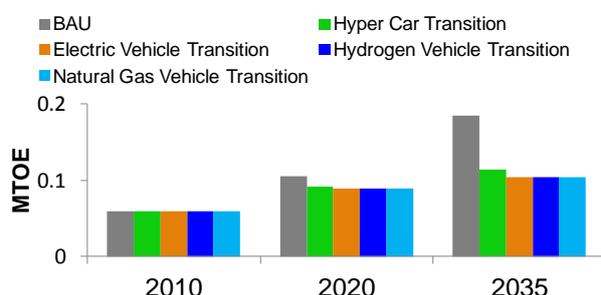
**Figure PNG14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure PNG15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 38% by 2035—even though these highly-efficient vehicles still use oil.

**Figure PNG15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



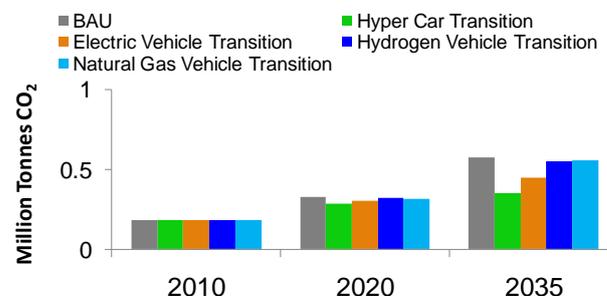
Source: APERC Analysis (2012)

Figure PNG16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from its oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Papua New Guinea, the Hyper Car Transition scenario is the winner in terms of CO<sub>2</sub> emissions savings, with an emissions reduction of 38% compared to BAU in 2035. The Electric Vehicle Transition scenario would offer a reduction of 22% in emissions in 2035, larger than in many other

economies due to the assumption none of the additional electricity would be generated from coal. The Hydrogen Vehicle Transition scenario would reduce emissions by 4% and the Natural Gas Vehicle Transition scenario would decrease emissions by 3% compared to BAU in 2035.

**Figure PNG16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# PERU

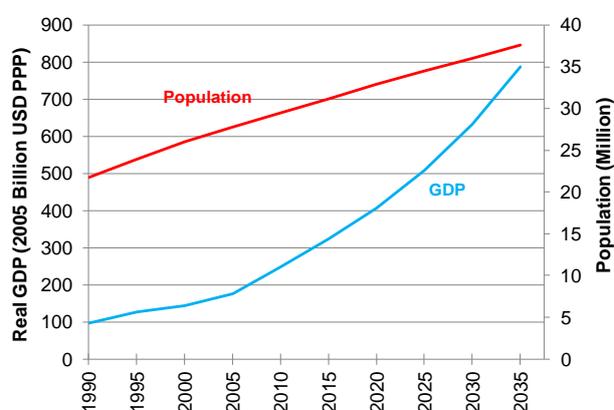
- *Although Peru is expected to remain a net gas exporter into the future, there is some uncertainty whether long-term production from the Camisea gas project will meet the economy's demand and export commitments, especially in the final years of the outlook period.*
- *The expected reduction in hydropower's contribution to electricity production, as fossil fuel use rises, will be the fastest growing source of CO<sub>2</sub> emissions over the outlook period.*
- *Peru has considerable potential for improving its energy efficiency; however, this will require the expansion of effective large-scale measures into the more energy-intensive sectors such as transport and electricity generation.*

## ECONOMY

Peru is a developing economy in South America and one of the three APEC Latin American economies. It has a land area of around 1.28 million square kilometres along the Pacific coast of the continent, bordering Ecuador and Colombia to the north, Brazil and Bolivia to the east, and Chile to the south. Peru's economic resources and climatic conditions are diverse; its climate zones range from tropical humidity in the Amazon rainforests, dry and cold in the Peruvian Andes' highlands, to hot and humid along the coast. Its complex biodiversity has led to Peru being listed as one of the 12 mega-diverse economies in the world (UNEP, 2002).

Peru is politically divided into 25 regions and the Lima Municipality, which is considered an autonomous region containing Lima, the capital city. With roughly nine million people, Lima is also the economy's largest urban and financial centre and is ranked fifth among Latin American urban centres (UN, 2008), containing 31% of the total Peruvian population (INEI, 2011b). Other important cities in the economy are Arequipa, Trujillo and Chiclayo.

**Figure PE1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Peru's urbanization in recent decades has been rapid, with an annual growth rate of 2.1% since 1990. As of 2010, around 77% of Peru's population is

considered urban, while 22% is still living in rural areas (UN, 2009). Peru's population, close to 29.5 million, is expected to grow at an average annual rate of 1%, reaching 37.6 million people in 2035.

Peru's economic growth since 2000 has been significant, with its GDP in constant currency terms increasing at an average annual rate of 5.7% from 2000 to 2010. Peru is the seventh largest economy in Latin America and the fifty-first in the world (IMF, 2011).

The main contributor to the economy is the services sector, which accounts for nearly 62% of Peru's GDP, followed by industry with 24% and agriculture with the remaining 14% (INEI, 2011a). The Peruvian economy is expected to grow considerably between 2010 and 2035, with GDP increasing at an annual average rate of 4.8%.

Growth in GDP per capita is expected to be less dynamic, with a projected annual growth rate of 3.7% over the same period, to reach almost USD 21 000 by 2035. Although Peru is considered a 'High Human Development' economy, placed eightieth in the world and eighth in Latin America on the basis of the United Nations' Human Development Index, the economy faces major challenges in terms of improving quality of life for its people. These challenges include increasing the proportion of the population with access to water and sanitation (Peru's rate is among the lowest in Latin America), as well as reducing the proportion of the urban population living in slums (currently about one-third) (UNDP, 2011; UN, 2008). In spite of some success in poverty reduction in the five years to 2011, Peru still struggles to improve general conditions, with 31% of its population considered poor and 10% considered extremely poor (INEI, 2011b).

Peru is a commodity export economy, with minerals, natural gas, fish and produce accounting for nearly 78% of its total exports. The mining sector is critical to the Peruvian economy, as it constitutes 4.3% of GDP, provides 61% of exports and is a key

destination for foreign direct investment in the economy, attracting 23% of the total (INEI, 2011a; MINCETUR, 2011; Proinversión, 2011). Peru is the world's top producer of silver, second of copper and zinc, third of tin, fourth of lead and mercury and sixth of gold (MINEM, 2010c).

After mining, the energy (oil and gas) industry is the most important in Peru, accounting for almost 1.4% of its GDP, making up almost 10% of its exports and representing 16% of the total foreign direct investment (INEI, 2011a; MINCETUR 2011; Proinversión, 2011). The remainder of Peruvian exports are mainly agricultural and fishing products.

Owing to Peru's diverse geography and climate, the economy is also exposed to several natural hazards. Earthquakes, tsunamis, volcano activity, droughts, and floods are not uncommon. In particular, Peru has been affected by the periodic climatic phenomena known as 'El Niño' and 'La Niña'—this sudden increase (El Niño) or decrease (La Niña) of equatorial ocean water temperature approximately every five years—that give rise to abnormal rainfall patterns that can go way above or below the norm, with severe economic consequences. The Peruvian Government estimated the economic losses caused in 1997 and 1998 by El Niño at over USD 3.5 billion (INDECI, 2010; NASA, 2011).

Transport systems in Peru are insufficient to keep up with demand growth and there are few options other than road transport, which is the dominant mode. Air transport infrastructure is limited, with most passenger and freight traffic going through Lima airport. The rail network is also fairly limited, and most traffic is for freight only. Water-based transportation is only employed in the Amazon river areas (MTC, 2005; MTC, 2011a).

The economy's road infrastructure comprises a total of 126 000 kilometres of roads maintained by three levels of government (central, state and local). The overall quality is poor, with less than 20% of Peruvian roads being paved (MTC, 2011c). In rural and poor areas such as in the Andes mountains, the roads' poor quality, or their absence, hinders economic growth by isolating populations from access to social centres and markets. With the help of the World Bank, a road construction program for the economy's poorest areas was implemented from 1995 to 2011. It is estimated that 3.5 million people benefited from this program, which included the construction of rural vehicle roads, pedestrian paths and fluvial corridors in the Amazon region (WB, 2010).

Bus services are the main public transport option across Peru, and small-sized vans (combis) and

minibuses (micros) provide most of the conventional passenger service in Lima. The informality and disorganization prevalent in their operations is not only responsible for their general inefficiency, but also for significant emissions (MTC, 2007). In the city of Lima, however, the 2010 introduction of an urban train line and a bus-rapid-transit (BRT) corridor (with vehicles operating on compressed natural gas) has significantly reduced the number of conventional vehicle commuter trips.

Peru's total vehicle fleet reached 1.8 million units in 2010, with nearly two-thirds of these in the Lima region (MTC, 2011b). In a move to benefit Peruvian families, car purchases were boosted in the 1990s by reducing import restrictions. This facilitated the importing of used cars, which has had an impact on the economy's vehicle fleet's renewal rate and average age—the fleet is considered old, with an average age of 17 years.

With no domestic vehicle manufacturers, all Peruvian vehicle sales come from imported stock, whether new or used. Most used units come from Japan and South Korea, requiring special facilities (CETICOs) to convert the right-wheeled Asian cars to the Peruvian left-hand-drive mode (BBVA, 2010).

In 2001, the government set maximum allowable vehicle emissions limits, calculated according to the vehicle's technology and fuel. The license required to import a vehicle now has stricter conditions applying to used cars, such as gasoline-fuelled vehicles not being older than five years, and diesel vehicles not being older than two. These criteria have reduced used car sales as well as their share in the economy's total car sales, falling from 83% in 2001 to 20% by 2010 (MTC, 2011a). By the end of 2012, the removal of the fiscal benefits granted to some CETICOs in combination with the reduction of taxes on the sales of new cars seems likely to reduce further the share of used cars into the Peruvian car fleet over the next few years (Gestión, 2013).

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Peru possesses a variety of natural resources, including a range of energy sources. Proved energy reserves total 582 million barrels of crude oil (1.24 billion barrels if natural gas liquids (NGL) are included), 0.35 trillion cubic metres of natural gas, 21.4 million tonnes of coal and 1800 tonnes of uranium located in the Puno region (MINEM, 2010a; MINEM, 2011). Of particular significance, the economy's natural gas reserves are the largest in South America after Brazil and Argentina (OGJ, 2011).

Peru produced 72 700 barrels per day (B/D) of crude oil and 84 500 B/D of NGL in 2010 (MINEM, 2010a). The economy's oil-refining capacity, which totals 213 300 B/D, is spread across six refineries (Conchán, El Milagro, Iquitos, La Pampilla, Pucallpa and Talara) (Petroperu, 2011; Repsol, 2011). Production of petroleum products in 2010 reached 74 620 million barrels, with gasoline and diesel making up half of the total output. Peru is a net oil importer. Not only is the domestic production insufficient to meet domestic demand, but most crude produced is of extra-heavy type, which cannot be processed in many of Peru's refineries. Of around 55 million barrels of total crude oil processed in Peru's refineries in 2010, the proportion of indigenous feedstock was 36%, while the remaining 64% was imported, mainly from Ecuador and Nigeria (MINEM, 2010a).

In contrast with its modest oil profile, Peru is considered a major South American gas producer. The Camisea project is the economy's major gas production area and is by far the most important energy project ever undertaken in Peru (Pluspetrol, 2011). This project began with the San Martín and Cashiriari gas fields, commonly known as 'Block 88', in the Ucayali basin in south-eastern Peru along the Camisea River. Although they were discovered in the 1980s, it was not until 2000 that a 30-year production contract was signed between the government and production companies, with development starting in 2004. In 2010 Peru produced around 7.2 billion cubic metres (255.6 billion cubic feet) of natural gas, a remarkable increase of 108.4% over the previous year. This was mainly due to the addition of Block 56 to the project; this block's output represented almost 40% of total production (MINEM, 2010a).

Although the initial aim of the Camisea project was to provide natural gas for domestic use, gas production increased rapidly since 2004, which has allowed the development of a liquefied natural gas (LNG) export market (MINEM, 2010a; PlusPetrol, 2011). In 2010, Peruvian LNG exports from its Melchorita plant amounted to 3.59 bcm, representing approximately half of Peru's total production (Perupetro, 2011).

Coal production in Peru is limited and the economy is a net importer. Peru's coal needs are met by 87% imports and 13% domestic production. Reserves amount to about 21 million tonnes and are located in the La Libertad, Ancash and Lima regions, with nearly all of them (95%) of anthracite type; bituminous coal makes up the rest (MINEM, 2011).

Peru's electricity infrastructure is based on the National Interconnected System (SEIN for its acronym in Spanish), which covers most of Peru—SEIN was created by interconnection of Peru's northern and southern power grids in 2001. There are also isolated power systems in areas where an extension of SEIN is not technically or economically feasible. Roughly 20% of the Peruvian population still lacks access to electricity (MINEM, 2010d).

Of Peru's total installed power capacity of 8612 MW in 2010, about 85% goes into public service via SEIN and 15% is used by on-site power systems isolated from the main grid, servicing municipalities and private users (MINEM, 2010b). Several private companies participate in electricity generation, transmission and distribution on SEIN and a remarkable proportion of the economy's electricity generation is based on hydroelectricity (approximately 46%). The rest comes from thermal power plants, which are fuelled by natural gas (33% of total electricity production), diesel and fuel oil (19%) and coal (2%). Increasing gas production and availability in recent years has stimulated gas use within thermal plants.

New renewable energy (NRE) sources for electricity generation, such as biomass and wind, represent only 0.3% of the total capacity (MINEM, 2010b, 2010d). However, the Ministry of Energy and Mines' (MINEM) projections for Peru's NRE-based power generation are promising. The potential contributions are estimated at 77 GW from wind energy and 60 GW from biomass. In addition, while there has been no formal assessment of geothermal energy potential in Peru, initial studies suggest sufficient resources to allow power generation projects. At the same time, potential resources of hydropower (which is not counted as a 'new' renewable energy source) has been estimated at 177 MW.

Peru's SEIN system has one international link with Ecuador. While further interconnections with electricity networks in Brazil and Colombia are planned in the near future, interconnection with Chile and Bolivia is prevented by the use of different frequencies in their electricity systems (MINEM, 2010d).

## ENERGY POLICIES

In Peru, the Ministry of Energy and Mines (MINEM) is responsible for development of energy policies and for guidance of the energy sector, as well as for addressing mining policies and issues. This reflects the major importance of these two sectors to the Peruvian economy.

MINEM is responsible for environmental issues concerning energy and mining activities. Through its different departments, the ministry covers all major areas of influence in the energy sector, oversees their activities and promotes investment to achieve sustainable development across the economy. In addition to MINEM, an autonomous regulatory organization created in 1996, Organismo Supervisor de la Inversión en Energía y Minería (Osinergmin) is in charge of setting electricity tariffs and gas transportation rates. Its goal is promoting efficiency in the power and gas sectors at the lowest possible cost for the customer.

In November 2010, MINEM issued Peru's Energy Policy Proposal 2010–2040. The goal of the policy is to meet Peru's energy demand in a safe, sustainable, reliable and efficient way, supported by planning, research and technological innovation. Its main objectives are achieving a diversified and competitive energy matrix with emphasis on renewable energy and energy efficiency; a competitive energy supply; universal access to energy supply; the highest possible efficiency levels in the energy production and utilization systems; self-sufficiency in energy production; and developing an energy sector with minimal environmental impact and low carbon emissions, as part of sustainable development (MINEM, 2010e).

In particular, the policy strives to develop the natural gas industry and extend its use in the residential, commercial, transport and industrial sectors as well as for efficient power generation. It also calls for strengthening institutions involved in the energy sector and joining regional energy markets in order to achieve Peru's long-term vision (MINEM, 2010e).

As Peru's economy has become gradually more open, free-market mechanisms such as competition and private operation have been implemented in industries such as mining, electricity, hydrocarbon and telecommunications. Several new laws have established a regime where domestic and foreign investments are subject to equal terms and this has encouraged foreign companies to participate in almost all economic sectors. Overall, Peru aims to ensure proper conditions to attract and retain investment by granting foreign investors equal treatment with Peruvians. Most activities are unrestricted, and there are a variety of schemes available under which investment can be made.

Under this regime, oil and gas upstream activities in Peru are conducted by private companies under licence or on service contracts granted by the government. In addition to MINEM, the

government-owned company Perupetro is in charge of assessing the technical aspects of the contracts granted. The government guarantees that the tax law in effect on the agreement date will remain unchanged throughout the contract term. Under a licence contract, the investor pays a royalty; whereas under a service contract, the government pays remuneration to the contractor. In both cases, the distribution of the economic rent (either as royalty or remuneration) is determined using two methodologies: production scales and economic results (Ernst & Young, 2011).

Before Camisea came online, Peru had developed only the Aguaytía gas field in its central region and some others in the northern department of Piura. Camisea, as one of the biggest gas reserves in South America and source of nearly all (more than 95%) of the natural gas in Peru, has been the basis of major development of the domestic natural gas industry (Osinergmin, 2008; MINEM, 2010a). The development is based on a model that aims for an open market with free competition in the production sector—with some government-set goals that participating companies have to meet. There is some government regulation of the transport and distribution activities, especially regarding tariffs (Osinergmin, 2008).

Electricity is a major issue within Peru's energy profile. When economic reforms began in 1992, one of the main targets of the Peruvian Government was the liberalization of the market to create an efficient, competitive and reliable electricity sector. This sector is now divided into three areas: generation, transmission, and distribution, with many private and government-owned power utilities participating in all of them. By law, electric energy dispatch and planning are carried out by the Electric Energy Operation and Dispatch Committee (COES for its Spanish acronym), which is a private and independent operator. To foster efficiency and competition, the legal framework prevents the participating companies from creating trusts and monopolies.

Peru's policies in the electricity sector have these objectives:

- reducing the economy's exposure to price volatility and helping ensure that consumers receive more competitive electricity tariffs
- reducing administrative intervention in generation price determination to promote market solutions
- creating effective competition in the generation market

- introducing a mechanism of compensation between SEIN and the isolated systems so that prices in the separate systems incorporate the benefits of natural gas production while reducing their exposure to the volatility of fuel markets.

Under this framework, there are regulated and non-regulated electricity prices, depending on the size of individual demand. ‘Free’ users are exempt from regulated prices due to their large demand (usually equal or more than 2500 kWh on their maximum annual demand), while users under 2500 kWh are subject to the regulated prices scheme.

Peru also has policy goals to increase use of renewable energy sources and support their development. The government aims to diversify renewable-based electric generation from the current significant reliance on hydropower. Modifications to the regulatory framework in 2008 added new features, including a five-year target for the share of domestic power consumption generated from renewable energy sources (excluding hydropower plants larger than 20 MW installed capacity); a firm price guaranteed for up to 20 years for successful bidders for energy supply contracts; and priority in dispatch and access to networks.

To achieve the renewable energy policy goals, MINEM established open auctions for renewable energy supply in order to ensure competitive conditions for electricity generators and customers. The first auction, finished in March 2010, added 411 MW in renewable energy capacity to SEIN; this was awarded in 26 projects using wind, solar, biomass or mini-hydro (Osinermin, 2011b). From a second auction, open in the second half of 2011, another 210 MW of capacity was added to SEIN. This consists of 102 MW small hydro, 90 MW wind power, 16 MW solar and 2 MW biomass from urban waste (Osinermin, 2011a).

In regard to biofuels, Peru’s regulatory framework also establishes a mandatory fuel blending of 7.8% of bioethanol in gasoline (this mix is known as gasohol) and 5% of biodiesel in traditional diesel (this mix is known as diesel B5).

Although Peru does not use nuclear energy for power generation, a government-run nuclear program has been in operation since 1975. In late 2009, Peru’s Nuclear Energy Institute (IPEN, for its acronym in Spanish) presented its Institutional Strategic Plan 2010–2016. This plan encompasses three main objectives, including the promotion of power generation based on nuclear energy (IPEN, 2009). In addition, Peru’s Energy Policy Proposal 2010–2040

considers nuclear energy development as an integral part of the economy’s energy matrix in the long term.

To promote energy efficiency, in 2009 MINEM published a Referential Plan for the Efficient Use of Energy 2009–2018. This document outlines the actions required in each sector to achieve the economy’s energy efficiency goals. The key goal is to reduce energy consumption by 15% from 2007 levels by 2018, through implementation of energy efficiency measures.

Subsequently, in May 2010, the Peruvian Government created the General Directorate of Energy Efficiency (DGEE) within the Vice-Ministry of Energy (through Supreme Decree No. 026–2010–EM). DGEE serves as the technical regulatory body in charge of the proposal and assessment of energy-efficient use and production, and non-conventional renewable energy issues. It also leads the economy’s energy planning, and is in charge of developing the National Energy Plan, which must incorporate actions for electricity sector development, in line with economy-wide development policies and the 2010–2040 Energy Policy framework.

Energy prices in Peru are partially subsidized. To strengthen macroeconomic development, the Peruvian Government created the Fund for Price Stabilization of Oil-derived Fuels in 2004. This aims to avoid price increases for final consumers resulting from high volatility in international oil prices. Using this mechanism, the government sets upper and lower price limits for producers and importers, to ensure the price stays within that range in spite of changing market conditions. In the case of fluctuations that drive the price above the limit, the difference is covered by the fund, through transfers to producers and importers; in the opposite situation, these parties will pay to the fund the difference between the actual price and the fund’s lower limit (El Peruano, 2010). As of early 2012, the fund was still operating, with considerable benefit for retail LPG, regular gasoline (84 and 90 octane), gasohol, diesel B5 and industrial fuel oil used for power generation (El Peruano, 2012).

As one of the economies most vulnerable to climate change, Peru has looked forward to implementing an effective and sustainable strategy for adapting and mitigating its effects. After the United Nations Climate Change Conference of Parties (COP16) held in Cancun, Mexico in late 2010, Peru submitted its Nationally Appropriate Mitigation Action (NAMA), which proposes to reduce the economy’s emissions by working towards several objectives. These objectives include reduction to zero of net deforestation of natural or primary forests;

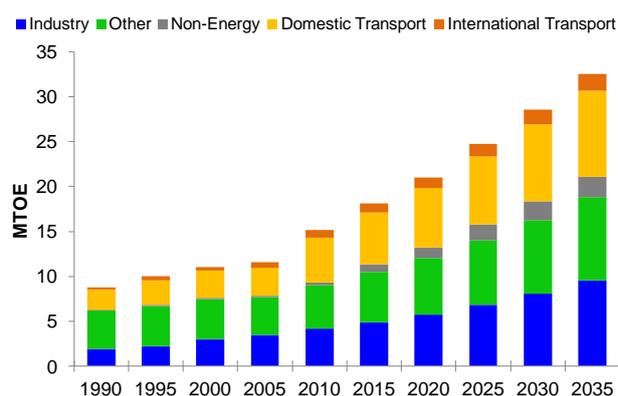
modification of the current energy grid, so that renewable energy (nonconventional energy, hydropower and biofuels) represents at least 33% of the total energy use by 2020; and implementation of measures to reverse the inappropriate management of solid waste (UN–FCCC, 2011).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Peru’s final energy demand (excluding the international transport sector) is expected to grow at an average rate of 3.1% per year, from 14.3 million tonnes of oil equivalent (Mtoe) in 2010 to 30.6 Mtoe by 2035 in the business-as-usual (BAU) scenario. In the long term, the most significant change is expected in the industry sector, which will expand its energy demand 130%, rising to 9.6 Mtoe in 2035. In 2035 the domestic transportation and industry sectors are expected to share the lead with a 31% share each, closely followed by the ‘other’ sector with 30%, and non-energy with 7%.

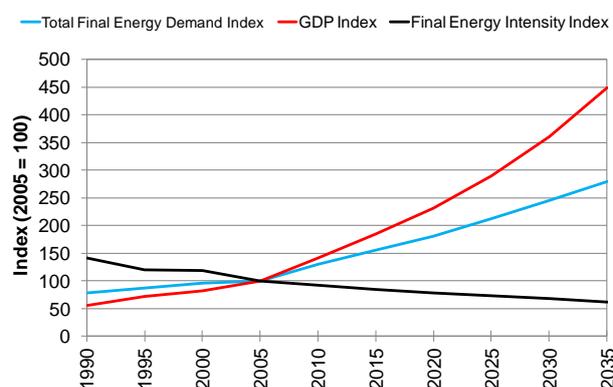
Figure PE2: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

From 2005 to 2035, Peru’s final energy intensity is expected to decline considerably, by 38% in comparison to 2005 levels.

Figure PE3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Reflecting its energy-intensive nature, Peru’s industrial energy demand is expected to increase at an average annual rate of 3.4% from 2010 to 2035. Gas demand is expected to experience the biggest increase over the outlook period, growing 243% from 2010, followed by electricity (141%) and oil (128%), while coal use is expected to slightly decrease (4%) in the same period.

Projections indicate that fuel shares in 2035 will remain fairly similar to 2010. The main changes are an increase in gas from 15% to 22% and decrease in coal from 15% to 6%. Although the share of natural gas in the Peruvian industrial energy demand is expected to grow, this will ultimately depend on the development of distribution networks to reach potential customers beyond Lima, which currently stands as the most important market. Energy intensity in this sector is expected to decrease by 38% from 2005 to 2035.

### Transport

As in other developing economies, Peru’s transport energy demand remains the largest of the final-use sectors. Due to a projected expansion of the economy’s total vehicle fleet by nearly 250% from 2010 to 2035, it is expected that energy demand in this sector will grow 92% in the same period (equivalent to an annual average growth of 2.6%). By 2035, energy demand will reach 9.6 Mtoe (11.5 Mtoe if international transport is included).

Road transport is expected to account for nearly all the transport demand, with oil-based fuels (gasoline, diesel and LPG) being the dominant energy sources. Biofuels demand is also expected to increase based on the growth of oil-based fuels, given Peru’s mandatory blending of gasoline with bioethanol and diesel with biodiesel. Development of other fuels and/or technologies in this sector seems unlikely and is not considered in the projection.

Some of the main factors that will affect the transport energy demand in the outlook period are:

- the expiration of import licenses for used cars, which will make for greater efficiency in the vehicle fleet as more new cars are sold—and which could ultimately promote the introduction of new technologies
- the building and expansion of CNG infrastructure and the success of the current CNG projects, such as the Lima BRT corridor
- aggressive transport policies that could call for construction of new mass transportation systems

- tighter environmental standards that might allow development of new technologies or setting of higher biofuels blending targets.

### Other

Reflecting the increased urbanization in Peru in the outlook period, energy demand growth in the ‘other’ sector (which covers residential, commercial and agriculture use) is expected to be moderately rapid, with an annual average growth of 2.6% reaching 9.3 Mtoe by 2035.

Electricity is the source expected to experience the fastest growth in ‘other’ sector demand (162%), closely followed by oil (mainly as LPG, 158%) and natural gas (138%). As Camisea gas production rises, natural gas and its by-product LPG are expected to increase their availability. While natural gas distribution grids are expected to expand in Lima and Callao replacing existing LPG and electricity demand there, in turn LPG’s greater distribution is expected to replace demand for less convenient fossil fuels (such as coal and kerosene) or non-commercial biomass.

In contrast, the demand growth in the ‘other’ sector for new renewable energy (NRE) is expected to be much lower. As non-commercial biomass is still widely used in Peruvian households for heating and cooking purposes in the form of firewood, dung and yareta (a dried moss-type plant), it is likely demand will decrease as more convenient energy options become available. Other commercial NRE sources such as solar may also come into production but on a small scale.

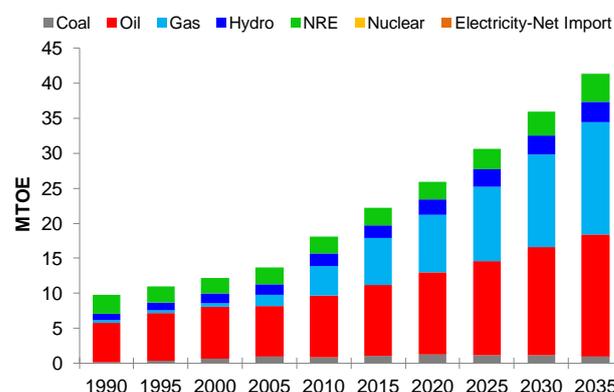
Nonetheless, the expected decrease in energy intensity in the ‘other’ sector will be greater than in Peru’s industry and transport sectors. Under the legal framework set by the Peruvian Reference Plan for the Efficient Use of Energy, several programs will operate until 2018, including replacement of incandescent bulbs by high-efficiency lamps, replacement of traditional electric boilers by solar technology in households, and replacement of stoves running on firewood and kerosene by new appliances based on natural gas and LPG. As a result, energy intensity in the ‘other’ sector is expected to improve significantly, decreasing 51% from 2005 to 2035.

### PRIMARY ENERGY SUPPLY

Peru’s primary energy supply is projected to increase by 129% in the outlook period, rising from 18.0 Mtoe in 2010 to 41.3 Mtoe in 2035. Fossil fuels (coal, oil and gas) are expected to remain the main energy sources, mainly due to the anticipated expansion in domestic supply of natural gas, with

their combined share of the primary supply expected to increase from 77% in 2010 to nearly 84% in 2035. The remainder of the energy supply will come from hydro and NRE. While gas supply growth is expected to grow most rapidly, increasing 282% from 2010 to 2035, growth from coal will be the lowest, expanding 15.1% in the same period.

Figure PE4: BAU Primary Energy Supply



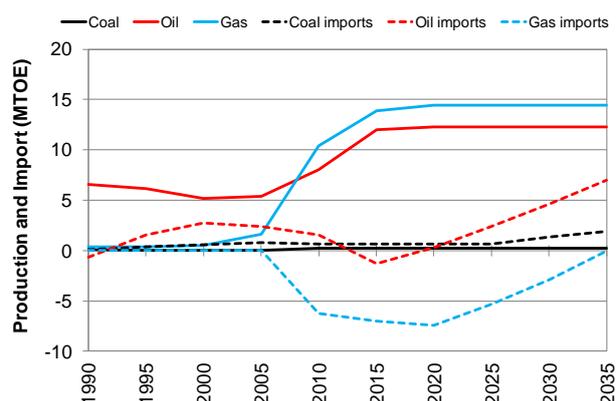
Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Under BAU assumptions, Peru is expected to continue as a net gas exporter based on its proven natural gas reserves, production and demand. However, as the Peruvian Government’s production forecasts are restricted to a 10-year span, gas production beyond that period is somewhat uncertain. In this regard, the assumptions made in this Outlook are that gas output will peak in 2016, and will be sustained around that level until 2035. The projection therefore indicates gas imports will be required in the last years of the outlook period to meet growing demand and whether gas imports are needed or not will ultimately depend on Peru’s capacity to strengthen its exploration and production and maximize Camisea’s output.

Projections indicate that Peru will remain an oil importer throughout the outlook period. Given its scarce oil reserves and limited production in comparison to expected demand, net oil imports are expected to grow 352%. In addition, since no major coal mining projects seem likely in the near future, coal imports will continue to be required to meet most of its demand.

Figure PE5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

From 2005 to 2035 Peru’s primary energy intensity will decrease by 33%. This is of special importance to Peru’s energy security given its role as a growing oil importer.

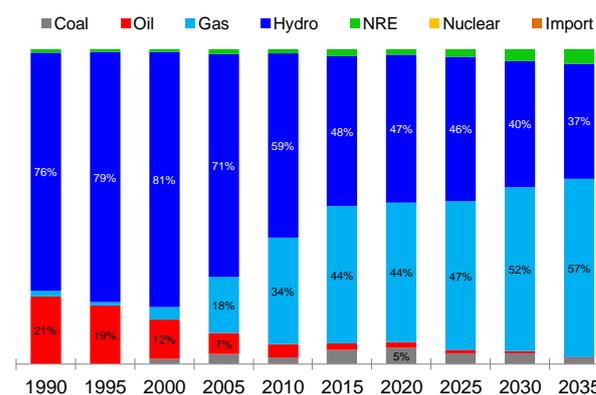
### ELECTRICITY

Electricity generation is projected to increase at an annual average growth rate of 3.7% from 2010 to 2035, reaching 92 TWh by 2035. As shown in Figure PE6, while the hydrocarbon share of the power generation mix in 2010 amounted to 40%, by 2035 it is expected to represent as much as 60% of total generation, with hydroelectricity and a much smaller share of NRE making up the remainder.

The increase in gas production is expected to support considerable growth in combined-cycle power technologies. In this case, power generation based on gas is projected to grow significantly, increasing 320% from 2010 to 2035, followed by coal (125%) and hydro (56%). Demand for oil-based fuels such as diesel and fuel oil is expected to decrease 87% by 2035, as the use of these fuels for electricity generation will largely be limited to areas where gas distribution or hydropower is unavailable.

The Peruvian Government’s efforts to raise the NRE contribution to the electricity generation mix will pay off in the long term. With an expected remarkable growth of 740% over the outlook period, NRE-based generation technologies will be the fastest growing energy source. The NRE share of total generation is expected to increase from 1% in 2010 to 5% by 2035. The mostly likely NRE development will be wind and biomass-fuelled power plants.

Figure PE6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

This projection does not consider any growth in international trade in electricity with Peru’s neighbours. With only one existing arrangement with Ecuador, further discussions in progress on interconnections with Brazil and Colombia will influence Peru’s future electricity supply.

### CO<sub>2</sub> EMISSIONS

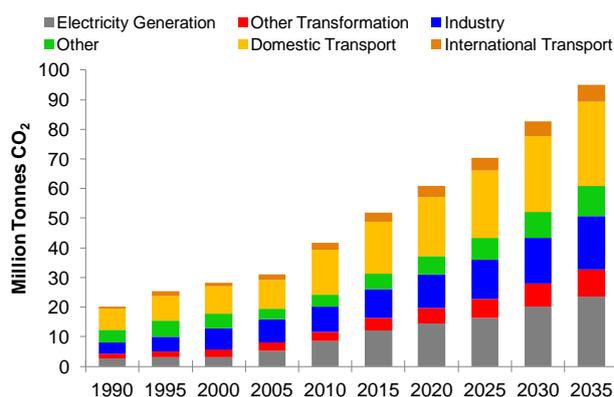
CO<sub>2</sub> emissions associated with the energy sector in Peru are projected to grow 128% from 2010 to 2035, from 41.8 million tonnes of CO<sub>2</sub> equivalent to 95.1 million tonnes of CO<sub>2</sub> equivalent. In 2035, final-use energy sectors are expected to make up most of these emissions (59%), followed by electricity generation (25%), refineries and energy sector own-use (10%) and international transport (6%).

Owing to the expected increase in natural gas use, especially in power generation, the projection indicates that oil’s share of total emissions will decrease, from 68% in 2010 to 60% in 2035, coal will reduce from 8% to 4% and the gas share will grow from 24% to 36%.

Even though Peru is seeking to diversify its power generation mix by promoting NRE and replacing fuel oil and diesel power plants, the expected reduction in hydropower contribution and increasing reliance on gas-fired technologies is expected to raise the share CO<sub>2</sub> emissions from electricity generation between 2010 and 2035 from 20% to 25%.

In terms of final-use sectors, the largest increases in emissions from 2010 to 2035 are expected to be in the ‘other’ sector (157%), industry (110%) and domestic transport (86%).

Figure PE7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

Table PE1 shows that from 2010 to 2035, Peru’s emissions will grow at about 3.3% per year. This will mainly be driven by GDP growth of 4.7% per year, offset declining energy intensity of GDP (improved energy efficiency and a shift to less energy-intensive industry) of 1.3%. The CO<sub>2</sub> intensity of energy will remain unchanged.

Table PE1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.5%	0.4%	0.1%	0.0%	0.0%
Change in Energy Intensity of GDP	-1.6%	-1.3%	-1.2%	-1.3%	-1.3%
Change in GDP	4.0%	7.2%	5.3%	5.1%	4.7%
Total Change	2.9%	6.2%	4.0%	3.8%	3.3%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

Although the Camisea project has helped Peru to achieve gas self-sufficiency and become a significant player in the international gas market scene as the only source of LNG exports in South America, the long-term evolution of the project is unclear. It is uncertain whether Peru will be able to continue to satisfy domestic demand and international export contracts.

There would appear to be an opportunity to develop policies to improve Peru’s energy efficiency, especially in the final demand sectors, given expected large increases in consumption and emissions. Energy intensity improvements implemented by the Peruvian authorities would provide numerous advantages to the economy. Energy security enhancement, reduction of growth in oil imports, maximization of gas value, increased productivity and ultimately, greater reductions in CO<sub>2</sub> emissions are some of the benefits Peru could gain by developing more ambitious energy efficiency policies.

### ALTERNATIVE SCENARIOS

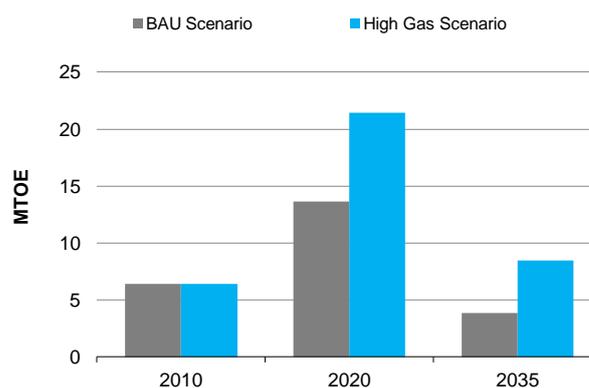
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies including Peru.

#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the Peruvian energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12.

This scenario was built around estimates of gas production that might be available at BAU scenario prices or below, if constraints on gas production and trade could be reduced. As shown in Figure PE8, under the High Gas Scenario gas production in Peru would be 121% larger in 2035 than under BAU.

Figure PE8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

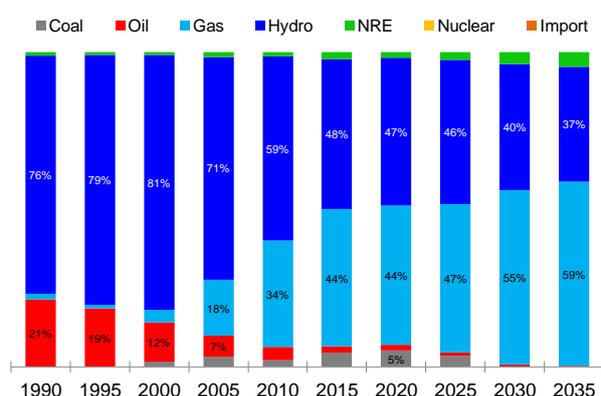
Assumptions about gas production were based on information provided by Peru’s MINEM on the total gas reserves (proved, probable and possible) from Blocks 56, 57, 58 and 88 of the Camisea gas project. While the BAU scenario only considers the development of proved gas reserves, the High Gas Scenario includes the probable reserves potential, resulting in much higher gas production. The High Gas Scenario assumptions also incorporate additional gas output from Block 58 coming online by 2025.

Under this High Gas Scenario, additional gas consumption in each economy will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. Irrespective of the significant investments required to develop the gas potential at Camisea, higher gas consumption in Peru’s domestic market entails considerable expansion in the pipeline network to

reach consumption centres beyond Lima. For this reason, it is probable that some portion of the additional gas production will be allocated for exports through Peru’s LNG plant, which may be expanded in the future.

The High Gas Scenario assumes that the main use for the additional gas production will be in the electricity generation sector as a replacement for coal. The effects of a larger gas contribution to Peruvian electricity generation are presented in Figure PE9. Since the BAU electricity generation mix shown in Figure PE6 already included a significant increase in gas-based electricity generation, raising it to 57% of total generation and replacing most coal generation by 2035, the gas share under the High Gas Scenario is only slightly larger. By 2035 gas would account for 59% of the total electricity generation mix in Peru, completely eliminating coal-based generation.

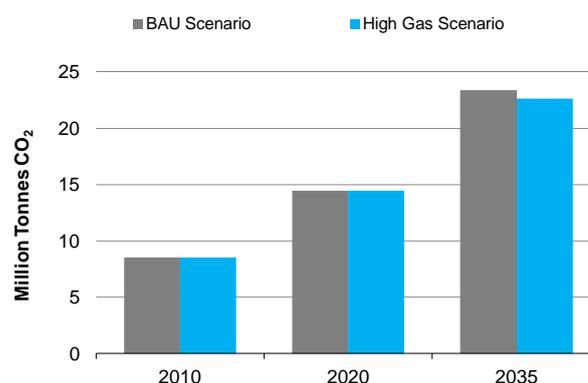
**Figure PE9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
 Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated and the expected increase in the gas-based electricity generation is very moderate in comparison with BAU, CO<sub>2</sub> emissions would only reduce 3% in 2035. Figure PE10 shows this CO<sub>2</sub> emissions reduction.

**Figure PE10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



Source: APERC Analysis (2012)

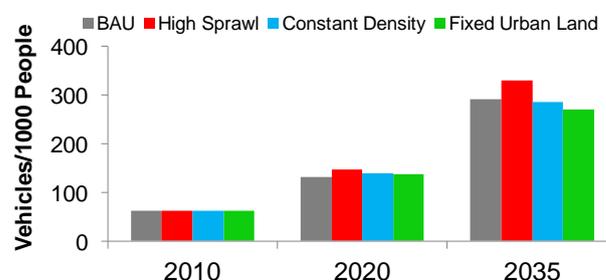
**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PE11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. By 2035, the High Sprawl scenario shows an increase of 14% compared to BAU, while the Constant Density and Fixed Urban Land scenarios showed a reduction of 2% and 7%, respectively.

In developing economies like Peru, the impact of urban planning tends to be relatively small. As vehicle ownership is still far from the saturation level, it will grow rapidly irrespective of urban planning. However, it should be noted that after 2035, there might still be significant impacts.

**Figure PE11: Urban Development Scenarios – Vehicle Ownership**

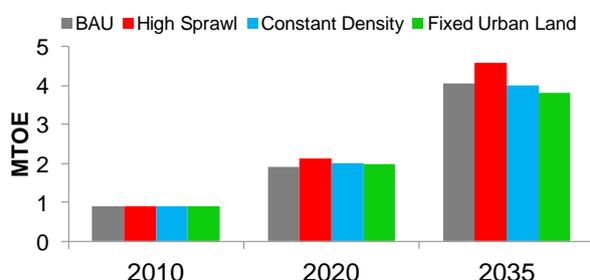


Source: APERC Analysis (2012)

Figure PE12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The results are similar to Figure PE11, with the highest variation being the

13% increase in 2035 compared to BAU occurring under the High Sprawl scenario, while the Constant Density and Fixed Urban Land scenarios showed a reduction of 1% and 6%, respectively.

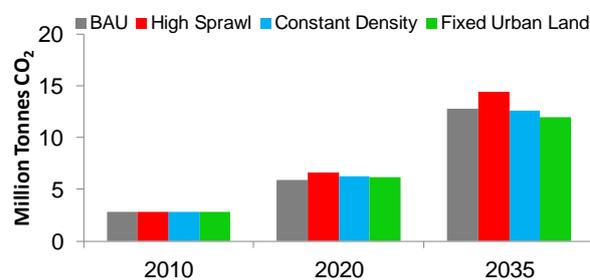
**Figure PE12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure PE13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure PE13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



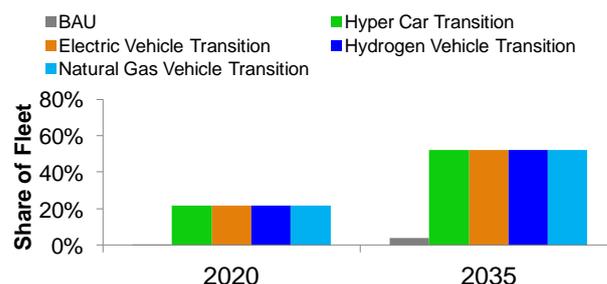
Source: APERC Analysis (2012)

### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PE14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 52% compared to about 4% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48%, compared to about 96% in the BAU scenario.

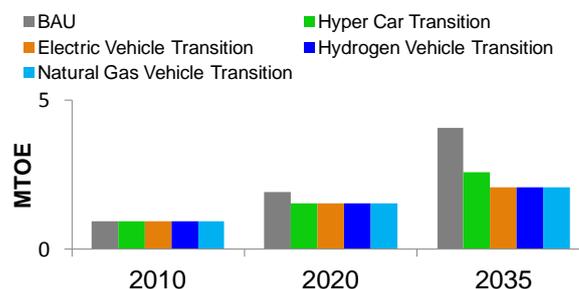
**Figure PE14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure PE15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 49% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 37% by 2035—even though these highly efficient vehicles still use oil.

**Figure PE15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



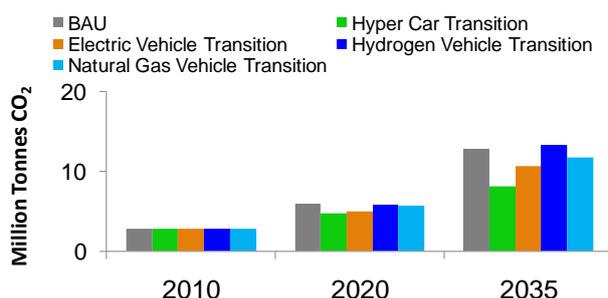
Source: APERC Analysis (2012)

Figure PE16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Peru, the Hyper Car Transition scenario appears to be the best option in terms of CO<sub>2</sub> emissions savings, with an emissions reduction of 36% compared to BAU in 2035. The next best reductions are the Electric Vehicle Transition (17%) and Natural Gas Vehicle Transition (8%) scenarios. Although hyper cars consume conventional fuels,

their efficiency levels would significantly reduce the amount of fuel required. In Peru, electric vehicles would also offer significant reductions because natural gas-fired generation would probably be the marginal source of the electricity. The Hydrogen Vehicle Transition scenario offers the least benefits, and in fact actually increases CO<sub>2</sub> emissions by 4% compared to BAU in 2035. Although hydrogen vehicles have little direct carbon impact, hydrogen fuel production is energy intensive, entailing significant indirect CO<sub>2</sub> emissions.

**Figure PE16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# PHILIPPINES

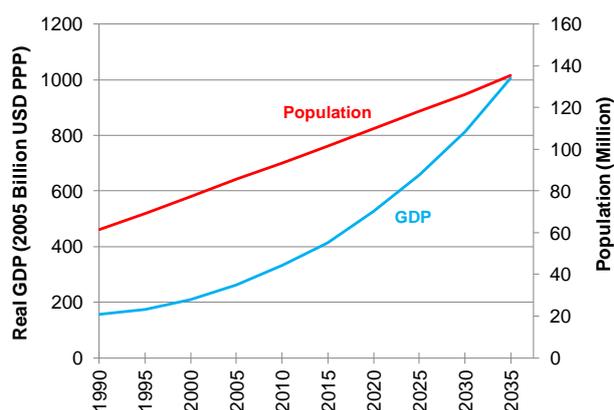
- *The Philippines is an economy which relies heavily on imported fossil fuel. The harnessing and use of renewable energy (RE) is a critical component of the Philippine Government's energy supply security strategy. The passing of the Renewable Energy Act of 2008 will ensure this challenge is addressed and the necessary RE policies put into action.*
- *Through its guiding vision, Energy Access for More, the Philippines Government hopes to put into action its national commitment to move energy access higher up the political and development agendas to become a key priority of the government.*
- *The government and the private sector will continue to forge strong partnerships to ensure the delivery of secure, sustainable, sufficient, quality and environment-friendly energy to all sectors of society.*

## ECONOMY

The Philippines is an archipelago of 7107 islands surrounded by South-East Asia's main bodies of water. It covers a total land area of 300 000 square kilometres, including inland bodies of water, spread over the three main island groups: Luzon, Visayas and Mindanao. Its total population in 2010 reached 93 million, with only 49% living in urban communities.

The population will continue to grow at 1.5% annually, reaching 135.2 million by 2035. An estimated half of the population lives in Luzon, the largest of the three major island groups and home of the Philippines capital, Manila. The growth for this outlook period is slower than the 2.2% rate during the period 1990–2005. During this earlier period, more than half of the total population was rural: by 2035, 61% of the total population will be urban.

**Figure RP1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

The Philippines economy grew a remarkable 7.6% in 2010 and will continue to show positive growth over the next 25 years—on average, 4.5% annually in real US dollars. This translates to real GDP of USD 1006 billion and a per capita GDP of USD 7450 by 2035. Overtaking Thailand, the second-largest economy in the Association of Southeast

Asian Nations (ASEAN), the Philippines is seen as one of the fastest growing economies in the ASEAN region over the outlook period (Ward, 2012). However, its high population growth rate will be a challenge in the economy's fight against poverty.

The industry sector is likely to continue to propel the growth in the economy, backed by a revived and strong manufacturing sector and renewed construction projects in the private sector. Growth in the manufacturing sector will remain robust due to export demand. The food industry will continue to experience a high growth rate due to the improved performance in the agriculture sector.

Most industries are concentrated in the urban areas around metropolitan Manila. The economy's biggest export processing zones are located within the Cebu metropolitan area and in some parts of Luzon. These processing zones provide the economy with a promising future in international markets. Electronics as well as semi-conductor materials, woodcraft and furniture, apparel and clothing accessories are the economy's top exports. These are assembled and/or manufactured in these processing zones.

The Philippines is primarily an agricultural economy. Its main agricultural crops are rice, corn, coconut, sugarcane, bananas and other tropical fruits. However, the rapid rates of urbanization and economic expansion have resulted in deforestation and the indiscriminate conversion of agriculture land for residential, industrial and commercial uses. This may undermine the economy's food security and forest resources, and has prompted the formulation of the Philippine Strategy for Sustainable Development. One of the strategies identified includes the "integration of environmental considerations in decision making, proper resource pricing, property rights reform, conservation of Biodiversity, rehabilitation of degraded ecosystem, strengthening of residual management (pollution control), control of population growth and human

resources development, inducing growth in rural areas, promotion of environmental education and strengthening of citizens participation” (PA 21, 1989).

The Philippines is located within the circum-Pacific belt, which means the economy frequently experiences seismic and volcanic activities. The volcanic nature of the economy is beneficial for the successful harnessing of geothermal energy resources.

The Philippines has a tropical maritime climate which is usually hot and humid, especially during the summer. This has the result of increasing electricity consumption due to the extensive use of air conditioning units and other cooling devices. The Philippines also sits astride the typhoon belt. This means the economy experiences torrential rains and thunder storms, some of which prove costly and damaging, destroying lives and property. The economy’s tropical climate, however, sustains a rich biodiversity, one of the richest in the world. Its lush forests, tropical islands, white sand beaches, lakes, rivers and mountains serve as the economy’s major tourist attractions.

The economy relies heavily on its road network to handle most of its passenger and freight movements. Large parts of the road network continue to be in a poor condition and only a small part of the total network is paved (such as the national roads and thoroughfares). Inadequate connectivity and the lack of a sustainable road safety strategy reduce the efficiency of the road network in promoting growth and providing safe access. This is likely to improve in the future, with the current administration’s vision of providing the public with quality infrastructure facilities by 2030 (DPWH, 2011).

Public transport services—mostly buses, jeepneys (the popular and inexpensive mass transport vehicles, originally made from US military jeeps left over from World War II and now part of the economy’s culture), tricycles (motorcycles with sidecars) and taxis—are predominantly privately owned and operated. The economy will continue to produce a number of light vehicles locally. However, imported used cars fuelled with gasoline and diesel will continue to form a significant part of the economy’s vehicle counts over the next 25 years. These imported used vehicles came mostly from Japan and Hong Kong, China which are converted to left-hand-drive vehicles in conversion bays and freeport zones in the municipality of Subic.

Three light rail transit lines provide some convenience to the riding public within the Manila metropolitan areas. The economy is attempting to

revitalize its ailing heavy rail transit, but an inefficient ticketing system and rundown stations have resulted in its poor ridership (World Bank, 2011).

There are eight international airports in the Philippines. The premier gateway to other parts of the world is the Ninoy Aquino International Airport in Manila. The other international airports are located in Clark, Subic, Laoag, Cebu, Davao, General Santos, and Zamboanga.

Being an island nation, water transport plays a major role in the movement of people and commodities. The economy has seven international seaports located in Manila (South and North Harbour), Batangas, Puerto Princesa and Subic (Luzon), Cebu (Visayas), Davao and Zamboanga (Mindanao). Inter-island passenger vessels ferry passengers to the different islands of the Philippines, while cruise liners call regularly into the port of Manila (DOT, 2009).

## **ENERGY RESOURCES AND INFRASTRUCTURE**

The Philippines has modest indigenous energy resources, accounting for the total production of 24 million tonnes of oil equivalent (Mtoe) in 2010 and projected to expand to 31.6 Mtoe in 2035. One-third of these resources are fossil fuels—3.5 Mtoe of coal (mainly lignite), 3 Mtoe of natural gas and 0.9 Mtoe of crude oil. The economy’s local crude oil production comes mostly from four oilfields: the Nido, Matinloc, North Matinloc and Galoc fields. The economy, through the Department of Energy (DOE), is gearing up to drill 25 oil wells every five years or a total of 100 wells by 2030. Hence, in addition to its current indigenous resources, the expected discoveries could mean the production of an additional 2.4 million barrels of oil per year by 2025 (DOE, 2010b).

The Philippines, however, imports most of its oil and is likely to continue to do so during the outlook period, to sustain the economy’s total petroleum requirements of 27.9 Mtoe by 2035.

The offshore Malampaya field is the largest producing gas field and the main source of gas in the economy, with an estimated daily production capacity of 450 million standard cubic feet (13 million cubic meters). It is also the main source of gas for the three large natural gas fired power plants in the Philippines. While gas production from this field is expected to be stable up to 2025, a potential gas discovery of 635 billion cubic feet (18.3 billion cubic meters) in the Sulu Sea is assumed to be developed and to produce gas during the same period.

While the demand for natural gas is mainly met by domestic production, efforts to ensure energy security will be enhanced. The economy will import natural gas to augment the projected demand beyond the production capacity from the Malampaya gas field. Feasibility studies are underway for potential locations for liquefied natural gas (LNG) import terminals (JICA, 2012, pp. 1–3).

Indigenous coal production accounted for 14% of the economy's demand for coal in 2010, and is estimated to reach 6.9 Mtoe by 2035. Domestic coal comes mainly from Semirara Island through the economy's only large-scale privately-owned coal producer, Semirara Mining Corporation. Indonesia is the economy's most significant coal trading partner, accounting for 96.7% of the total coal imported.

The Philippines' installed electricity generating capacity stood at 16 GW in 2010, and is projected to increase to over 58 GW by 2035. Fossil fuels will continue to dominate the economy's total power generation; coal thermal alone is expected to provide almost 70% of its electricity generation by 2035, followed by natural gas with a 16% share.

In view of the economy's abundant renewable resources, by 2035 more than 50% of its indigenous energy resources are expected to come from renewable energy, such as hydro and geothermal as well as other new and renewable energy (RE) sources. Other RE sources include biomass (like fuelwood and bagasse, the fiber left after juice has been squeezed from sugarcane stalks, etc.), which is mainly used in household and commercial applications. The Philippines benefits from its tropical maritime climate with its wind and solar sources of energy, and the economy is looking at the possibility of its first ocean energy facility by 2018 (Layug, 2012).

Among the renewable energy sources, geothermal energy is expected to provide the biggest contribution over the next 25 years. The economy's installed geothermal generating capacity of 1966 MW in 2010 placed the economy as the second-largest geothermal producer in the world behind the United States (US) (IGA, 2010). The passage of the Renewable Energy Act of 2008 (RE Act) will provide the direction for the economy to harness and utilize its renewable energy. A firm commitment from the private sector, particularly on funding, will likely provide the economy with an additional capacity of 9.2 GW from geothermal, hydro, biomass, wind, solar and ocean sources by 2035.

In 2010, the electrification level of the economy at a household connection level was 68% (NSO, 2010); at a barangay level (a village, district or ward, i.e. the basic political unit) it had reached 99.89%.

The economy envisions a 90% household electrification level by 2017. Due to its geography, the economy has a complex energy system. Major power grids are separated according to its three major islands, Luzon, Visayas and Mindanao. In the Luzon grid, more than half of its capacity is coal-fired; Visayas is home to the economy's vast geothermal resources; while more than 50% of the Mindanao grid's energy requirement is sourced from hydro. The interconnection of the three major grids is not expected in the near future. Smaller islands are interconnected to the major island grids to provide service to remote areas. Where it is not economical to connect a small island to a major grid, separate local systems are being established around small generating plants (NGCP, 2011).

## ENERGY POLICIES

The Philippines, through collaborative efforts with key economic development agencies, will continue to formulate plans and programs to maintain its positive growth for the next 25 years. The implementation of infrastructure projects by the Department of Public Works and Highways (DPWH) and the Department of Transportation and Communication (DOTC) will help to promote the economy's growth. Assuming the industry sector continues to show good performances over the outlook period, the economy will achieve its economic objectives (Navarro and Yap, 2012).

As the major instrument for realizing the energy sector's vision of achieving energy independence, the Department of Energy (DOE) is currently crafting the 2012–2030 Philippine Energy Plan (PEP). The 20-year plan will reflect the government's mission to ensure the delivery of secure, sustainable, sufficient, affordable and environment-friendly energy to all economic sectors. The energy sector's guiding vision, Energy Access for more, will ensure a larger population has access to reliable and affordable energy services, most importantly for local productivity and economy-wide development. With this guiding vision, the economy hopes to put into action its national commitment to move energy access higher up the political and development agendas to become a key priority of the government (DOE, 2010a).

To attract more investors into the exploration and development of its indigenous oil and gas resources, the economy conducts an annual Philippine Energy Contracting Round (PECR) or energy contracting round mechanism. As of 2009, 34 service contracts (SCs) have been supervised and monitored by the DOE and the number is likely to increase to 117 by 2030. Private companies enter SCs

with the DOE for the exploration of oil concession areas and natural gas deposits and for the development of geothermal resources and certain coal areas in the economy, subject to sharing their net proceeds with the government.

The economy hopes to achieve a production level of 8.59 million barrels of oil, 294 billion cubic feet (8.49 billion cubic metres) of gas and 87.58 million barrels of condensate by the end of 2030. Assuming these targets are realized, hydrocarbon resources level will reach 45% by 2035 from the 2010 production level of 30%. The economy has 16 sedimentary basins, the majority of which are in Luzon, particularly in Palawan.

Through the PECR, and the conversion of existing coal operating contracts from the exploration to the development stage, the entry of more investors is anticipated. Considering private coal exploration investors and the state-owned Philippine National Oil Company Exploration Corporation (PNOC EC) together, the economy's indigenous coal production is likely to increase from its 2010 level of 3.5 Mtoe to 6.9 Mtoe by 2035.

The Philippines is projected to rely heavily on imported fossil fuel, even after 25 years. The RE Act will ensure this challenge will be addressed and the necessary RE policies will be put into action. Through its National Renewable Energy Program, the economy's current RE based grid-connected installed capacity of 5440 MW is targeted to triple by 2030. Most of this capacity will come from hydro and wind power (DOE, 2011). The RE Act will likewise address possible bureaucratic constraints in developing RE by streamlining the registration process and promoting transparency and open competition. Future policy requirements to commercialize RE, such as the formulation of a feed in tariff (FIT) and bidding for its allocation, are being developed.

The Philippines' downstream oil industry was deregulated in 1998 and is currently dominated by two major oil refining and marketing companies; Petron Corporation and Pilipinas Shell. A third oil refiner and marketer, Caltex Philippines Inc., converted its 86 500 barrels per day refinery into an import terminal in 2003 and now operates as a marketing and distributing company under the name Chevron, but maintains its Caltex brand. Petron Corporation was jointly owned by PNOC, a state-owned company, and the Aramco Overseas Company, but it was privatized in 2010.

The Downstream Oil Industry Deregulation Act of 1998 allows oil companies to set their own unregulated prices based on competition in local

markets. Oil deregulation does not guarantee lower prices but does guarantee fair prices. As mandated, the DOE monitors the prices of both the raw material crude oil and the refined petroleum products in the international market.

As embodied in the Electricity Power Industry Reform Act (EPIRA), the economy's electricity supply industry has been restructured paving the way for the privatization of the state-owned National Power Corporation (NPC). The restructuring calls for the separation of the different components of the power sector namely, generation, transmission, distribution and supply. Transmission and distribution exhibit natural monopoly characteristics which make the regulation of them appropriate. The generation and retail sale of electricity, on the other hand, can be efficient in the competitive environment as a result of the reforms introduced by the EPIRA. The privatization of NPC involves the sale of the state-owned power generation and transmission assets (e.g. power plants and transmission facilities) to private investors.

While oil pricing is deregulated, electricity pricing is a regulated energy commodity. The price for electricity is set by the Energy Regulatory Commission (ERC). Alongside the implementation of the EPIRA is the unbundling of electricity rates. The individual charges for providing specific electric services to any end-user, for generation, transmission, distribution and supply, are identified and separated. The ERC determines the rate-setting methodology taking into account the relevant considerations that will enable a specific entity to operate viably, with the end view of providing a reasonable price for electricity. Part of the EPIRA law is the birth of the Wholesale Electricity Spot Market (WESM) which serves as a venue where electricity made by power-producing companies is centrally coordinated and traded like any other commodity in a market of goods. After several months of trial operations, in June 2006 the WESM started commercial operations in the Luzon grid. Four years into its commercial operations in Luzon, the Visayas grid was integrated into the WESM and it commenced commercial operations in that grid in December 2010. The establishment of the WESM creates a level playing field for the trading of electricity among WESM participants; hence third parties are granted access to the power system. Although prices are still governed by commercial and market forces, customers may have the option to buy energy at a price lower than the regulated rate (WESM, 2012).

By virtue also of EPIRA, the energy sector through the DOE is mandated to formulate the Power Development Plan (PDP) which is integrated

into the PEP. The PDP outlines a strategic roadmap for the power sector to ensure and secure the delivery of a reliable and quality electricity supply in the short-term, medium-term and long-term planning periods.

In view of the Philippines' wide-ranging geographical situation, to fully connect the entire population to the national grid is a significant hurdle. Servicing the most remote and difficult to electrify rural areas will require significant resources; hence achieving a 100% electrification level over the outlook period remains a challenge for the economy. The government through DOE and other private and government agencies spearheads the development of various innovative service delivery mechanisms designed to increase access to electricity services. One of its efforts is the Expanded Rural Electrification Program which aims to at least provide some access to electricity for the marginalized and other off-grid areas. This will be done through decentralized energy systems such as battery charging stations (BCS), individual solar home systems, micro-hydro systems, and wind turbine energy systems (Salire and Muhi, 2010).

The National Electrification Administration (NEA), an attached agency of the DOE, is the economy's prime mover in rural electrification and the DOE's arm in the implementation of the decentralized energy systems. NEA currently supervises 96 electric cooperatives by providing quality financial, institutional and technical services to franchise areas not covered by the Manila Electric Company, the economy's biggest privately-owned utility.

Meanwhile, NPC remains as an economy-wide government-owned and controlled corporation which performs the missionary electrification function through the Small Power Utilities Group (SPUG). SPUG is responsible for providing power generation and its associated power delivery systems in areas not connected to the transmission system.

The Biofuels Act of 2006 provides the economy with a way of hedging against escalating oil prices and of reducing the economy's dependence on imported fossil fuels. The Act currently mandates a minimum 1% biodiesel blend in diesel and a 5% bioethanol blend in gasoline. The economy hopes to increase this to 20% coco methyl ester (CME) in diesel and 20% ethanol in gasoline by 2030. CME is domestically produced from coconuts, while 80% of the bioethanol supply will be sourced from imports due to the limited domestic production capacity.

Alongside its efforts to curb the economy's dependence on imported oil, the Philippines Government considers the use of alternative fuels in

the transport sector a priority. As well as its target to replace the current number of conventionally fuelled vehicles with alternative technologies and fuels by 2035, the economy expects to add more infrastructure such as natural gas pipelines, refilling stations for CNG (compressed natural gas) buses and charging stations for electric vehicles. Operators who participate in the natural gas vehicle (NGV) program receive incentives such as an income tax holiday and a 0% rate of duty on imported NGVs, NGV engines and other NGV industry items. There is a proposal to enhance the existing incentives for the program to encourage more participants. Over the next 25 years, the economy has a target to increase the number of vehicle engines running on higher percentages of biofuels, while electric vehicles in both private and public transport will become mainstream.

Mass transport systems in some of the economy's biggest cities are likely to improve in the future. For example, a feasibility study on a bus rapid transit (BRT) system for Cebu is being done with the help of the World Bank and AusAID (DOTC, 2010).

The government also aims to attain a better interconnection between the economy's islands, to open up new economic opportunities, to reduce transport costs and to increase access to social services. Priority infrastructure projects include: the completion of the nautical highway system (an integrated network of highway and vehicular ferry routes), with several projects that will spread development and provide new opportunities for growth in other regions to decongest metropolitan Manila; better access to tourist sites; and improvements in underdeveloped regions and roads (World Bank, 2011).

Economic growth and increasing energy use clearly indicate the economy is likely to face the realities of high oil prices and greater competition for energy resources in the long term. As a way of hedging against the high cost of oil, the National Energy Efficiency and Conservation Program (NEECP) is seen as an essential strategy in rationalizing the economy's demand for petroleum products and eventually lessening the impact of escalating prices on the economy (DOE, 2009).

Through the NEECP, the energy sector will work on developing and promoting new technologies. It will also conduct a major information campaign to promote the practice of sensible energy habits in homes, businesses and motor vehicles. Specifically, activities under the program include: the Fuel Economy Run (which involves participating private vehicle manufacturers and assemblers showcasing the fuel efficiency of their vehicles); the

provision of awards to establishments observed to achieve significant energy savings in their operations; and educational campaigns in schools, households, and municipalities. To ensure wider coverage the economy conducts tri-media campaigns, with the hope of achieving an annual 10% reduction in its total energy demand by 2030 (Reyes, 2012).

In addition, the economy is implementing the Philippine Energy Efficiency Project which aims to demonstrate the societal benefits of a series of energy efficiency projects in the different sectors—such as the public, commercial and residential sectors. The project's key targets include: the retrofit of 135 government buildings with energy efficient lighting systems; the economy-wide distribution of compact fluorescent lamps (CFL) totalling 8.6 million CFL units; and the retrofit of public lighting (street and traffic lights) using light emitting diode (LED) lamps in three major cities. The project quantification of economic and environmental benefits showed a 243 MW deferment of power generating capacity additions, a reduction of oil imports by 83.1 kilotonnes of oil equivalent (ktoe), and the avoidance of 172 kilotonnes of CO<sub>2</sub> emissions.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

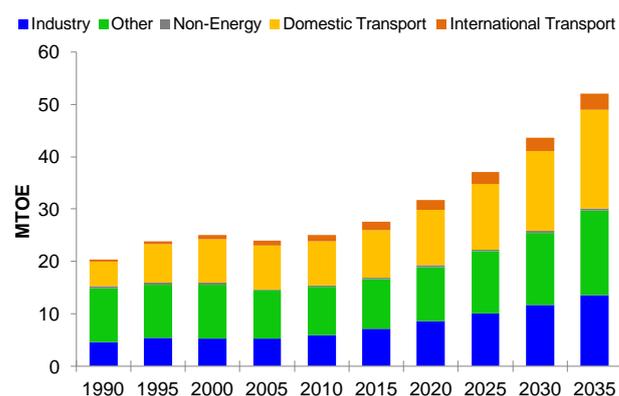
The Philippines' final energy demand is expected to expand at an average annual rate of 2.9% from 2010 to 2035. This translates to a total final energy demand of 49 Mtoe by 2035, from the 2010 level of 23.8 Mtoe.

Together with the economy's fast-paced growth, the industry and domestic transport sectors are both projected to grow at an average annual rate of 3.3% over the next 25 years. Growth in the industry sector will be driven by the projected expansion of the machinery industry, whose energy demand will increase by 5% annually during the same period.

The transport sector (includes international transport sector) is expected to dominate total final energy demand over the outlook period, accounting for a 42% share by 2035. The 'other' and industry sectors' energy demands are estimated to account for 26% and 31%, respectively, of the economy's final energy demand by 2035. The non-energy sector's demand is very small, with only a 1% share of the total final energy demand in 2035.

While oil consumption is projected to continue to dominate the economy's final energy demand through to 2035, gas consumption shows a positive boost of 4.8% annually over the 25-year outlook period.

Figure RP2: BAU Final Energy Demand

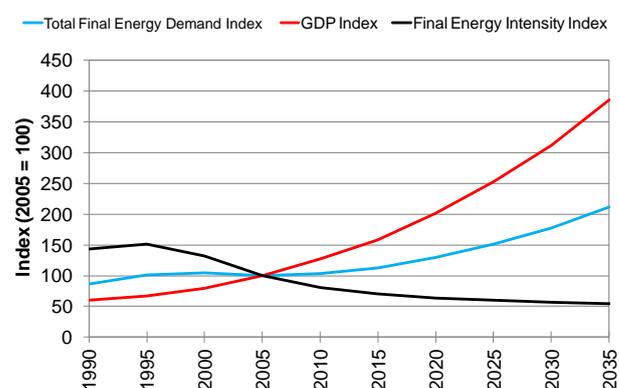


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to reduce by 45% from 2005–2035.

Figure RP3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

The industry sector's fuel consumption of 6 Mtoe in 2010 will reach 14 Mtoe by 2035, which is almost one-third of the economy's final energy requirement in 2035. Heavy-use industries are dominated by food and tobacco products and non-metallic minerals—they are expected to collectively use more than 60% of the industry energy demand by 2035.

The demand for natural gas in the industry sector will grow the fastest, at an annual rate of 4.8% in the next 25 years. Coal consumption, which dominated the industry sector's energy demand in 2010, is likely to be displaced by a demand for electricity by 2035. It is estimated that electricity use will grow at a rate of 3.6% annually over the outlook period.

### Transport

Energy demand in the domestic transport sector will grow alongside that in the industry sector.

Transport energy demand will absorb more than one-third of the economy’s total fuel requirement during the 25-year outlook period. The sector’s total demand will expand to 19 Mtoe by 2035 from the 2010 level of 8.4 Mtoe. Petroleum consumption in the sector is not expected to respond strongly to oil price increases. It accounts for 67% of the economy’s total oil requirement by 2035.

The light vehicle fleet is expected to increase significantly, with an annual growth rate of 3.4% over the outlook period. By 2035, the fleet is projected to be made up of 40% conventional gasoline and 19% diesel vehicles, and about 6% all other types of vehicles, mainly LPG and conventional hybrids. The remaining 35% of the light vehicle fleet will be motorcycles.

**Other**

The ‘other’ sector will account about one-third of the economy’s total energy demand and will grow at an average annual rate of 2.3% during the outlook period. This translates to an increase from the 2010 demand level of 9.2 Mtoe to 16 Mtoe by 2035. Electricity will be the dominant fuel used and it will grow the fastest, at an average annual rate of 4.4% over the next 25 years. It is assumed this growth will reflect the changing fuel preferences over the outlook period, as traditional biomass use in the sector contracts rapidly at a rate of 6% annually.

The residential sector’s energy demand (60%) is likely to remain the main contributor in the ‘other’ sector’s total energy consumption. This is due to the continuing growth of the economy’s population and GDP in the next 25 years. Energy demand in this sector is expected to grow 1.7% annually during the outlook period.

The commercial sector is projected to be one of the drivers of the Philippines economy due to the continuing expansion in the number of business process outsourcing companies (such as call centres) taking place in the economy (PhilBPO, 2011). With this in view, the energy requirement in this sector is likely to grow faster than that in the residential sector, at 3.5% annually over the next 25 years.

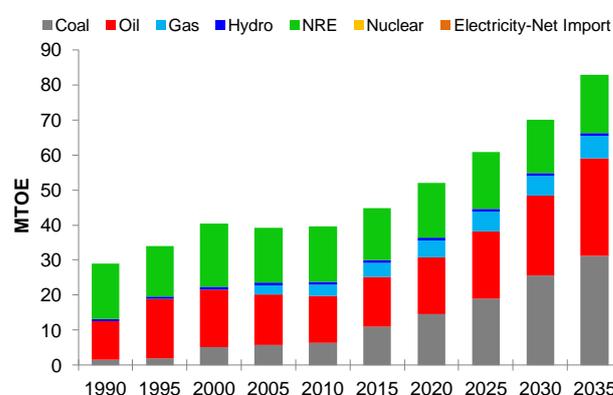
Agriculture plays a significant role in the Philippines economy. Its produce, such as fruits, vegetables and other crops as well as livestock and poultry, is projected to post strong export performances over the next 25 years (PIDS, 2009). The modest increase (1.9% annually) in energy consumption for the sector during the outlook period is driven by an increase in the demand for petroleum products, used mainly for farm machinery and

implements, and for electricity, used largely in the livestock and poultry sub-sectors.

**PRIMARY ENERGY SUPPLY**

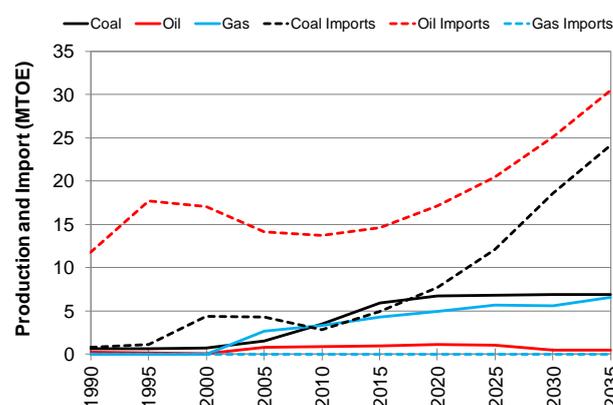
Oil will continue to dominate the economy’s energy mix from 2010–2025, accounting for one-third of its total primary energy supply. This is mostly driven by the transport sector which will consume more than 60% of the economy’s total oil supply during the period. In terms of growth, coal will grow the fastest at an average annual rate of 6.5% during the outlook period. By end of 2025, coal is likely to exceed oil in the primary energy supply, mainly as a result of coal use for electricity generation.

*Figure RP4: BAU Primary Energy Supply*



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

*Figure RP5: BAU Energy Production and Net Imports*



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

The Philippines’ total primary energy supply is projected to grow moderately at an annual rate of 3% over the next 25 years. This translates to the 2010 supply level of 39.6 Mtoe expanding to 83 Mtoe by 2035. Its modest domestic production of energy resources will not sustain the economy’s fuel requirements over the outlook period. Hence, the economy will continue to rely mostly on imports.

While new gas finds and other potential indigenous coal and renewable energy sources are projected to come into production within the outlook period, more than half of the economy’s requirements will be imported. Consequently, most of the economy’s oil supply will be imported, reaching 30 Mtoe of oil imported by 2035, from its 2010 level of 13.7 Mtoe.

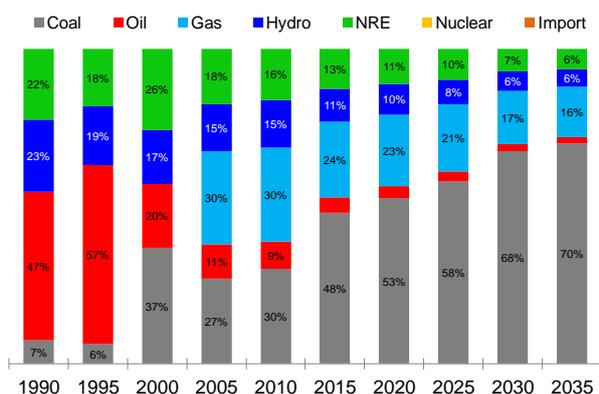
Due to the significant contribution of coal in the economy’s energy mix, particularly with coal generation reaching about 70% of total electricity generation by 2035, a total of 28 Mtoe of coal will be needed over the outlook period. Indigenous coal production is estimated to increase at an average annual rate of 2.7% from its current level, to reach 7 Mtoe by 2035. However, the economy’s coal imports will continue to grow over the outlook period.

The economy’s new renewable energy (NRE) supply is expected to continue to contribute significantly to the total primary energy supply. Despite a modest annual growth rate of 0.2%, NRE will likely account for about 20% of the economy’s total primary energy supply by 2035.

**ELECTRICITY**

The economy’s total power generation will increase by 4.2% during the outlook period. This translates to an increase from the 2010 level of 67 TWh to 187 TWh by 2035.

*Figure RP6: BAU Electricity Generation Mix*



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

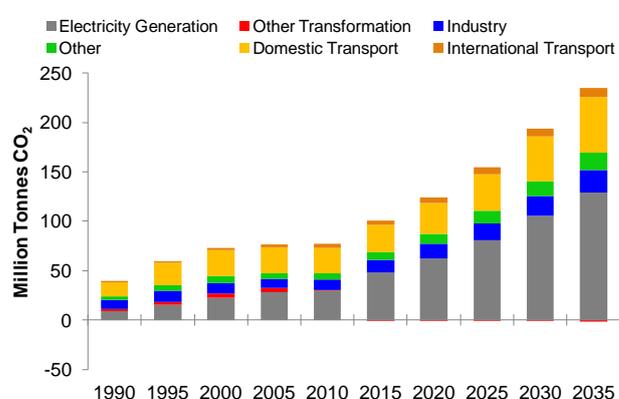
Electricity output from coal is likely to dominate power generation, accounting for more than half of the economy’s total gross generation by 2035. The output from coal generation will reach 130 TWh by 2035, up from 20 TWh in 2010. Electricity generated from hydro and NRE will increase modestly by less than 1% annually from 2010 to 2035, posting a combined output of 22 TWh by 2035. Currently,

natural gas accounts for almost 30% of the economy’s power generation and is expected to increase moderately by 1.7% annually over the next 25 years.

**CO<sub>2</sub> EMISSIONS**

APERC’s projection showed the economy’s CO<sub>2</sub> emissions increasing 4.5% annually during the outlook period. This translates from CO<sub>2</sub> emission levels of 75.9 million tonnes in 2010 to 230.2 million tonnes by 2035. This is due to the projected increase in fossil fuels consumption, especially in coal for power generation. Emissions from electricity generation grow by 6% per year and from coal-fired generation by 7.4% per year.

*Figure RP7: BAU CO<sub>2</sub> Emissions by Sector*



Source: APERC Analysis (2012)

The Table RP1 shows the total change in CO<sub>2</sub> emissions from fuel combustion will be influenced largely by the change in GDP, and the reduction in energy intensity of GDP (energy efficiency) will be mostly offset by the CO<sub>2</sub> intensity of energy (fuel switching to increase the use of fossil fuels, especially coal).

*Table RP1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion*

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	2.4%	-0.2%	1.3%	1.2%	1.5%
Change in Energy Intensity of GDP	-1.3%	-4.3%	-2.1%	-1.9%	-1.5%
Change in GDP	3.4%	4.9%	4.6%	4.6%	4.5%
<b>Total Change</b>	<b>4.6%</b>	<b>0.3%</b>	<b>3.8%</b>	<b>3.8%</b>	<b>4.5%</b>

Source: APERC Analysis (2012)

**CHALLENGES AND IMPLICATIONS OF BAU**

Under business-as-usual assumptions, the Philippines projections reflect positive economic growth, in line with the economy’s own projections. This will be matched by a corresponding growth in energy demand. The Philippines Government has a vision to achieve energy independence, and a goal to ensure the delivery of secure, sustainable, sufficient,

affordable and environment-friendly energy to all economic sectors.

The birth of a natural gas industry brings the Philippines closer to the government’s goal, and has earned the economy a place alongside other significant Asian economies in the APEC region’s natural gas markets. It remains to be seen whether the extent of the economy’s natural gas supply will be sufficient for its domestic requirements. The Philippines’ natural gas industry can still be considered young, meaning there is a vast opportunity for developing policies to ensure the full achievement of its goal.

Despite its low per capita emissions of 1.7 tonnes of CO<sub>2</sub> by 2035, the BAU projection indicates that the growth rate of CO<sub>2</sub> emissions in the Philippines will be high at 4.5% annually from 2010–2035. This alarming rate should spur the economy into taking measures to ensure environmental sustainability. Since the electricity sector has the highest emissions growth, it is proposed that improvement measures should focus on this sector. This will happen by improving energy efficiency in the electricity generation, transmission and distribution sub-sectors as well as intensifying the implementation of the RE Law which would consequently reduce fossil fuels consumption.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

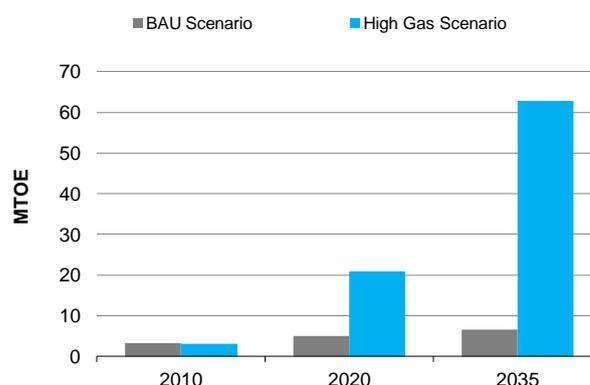
#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario in the Philippines assumed natural gas production would reach 62.7 Mtoe in 2035, 10 times more than the production level under BAU (see Figure RP8). This potential production scenario was taken from a joint study done in cooperation with the Japan International Cooperation Agency (JICA, 2012). The increase in production will begin to take place in 2017, with production levels twice those under the BAU scenario in that year. This additional gas

production will mostly likely come from the Malampaya gas fields.

Figure RP8: High Gas Scenario – Gas Production



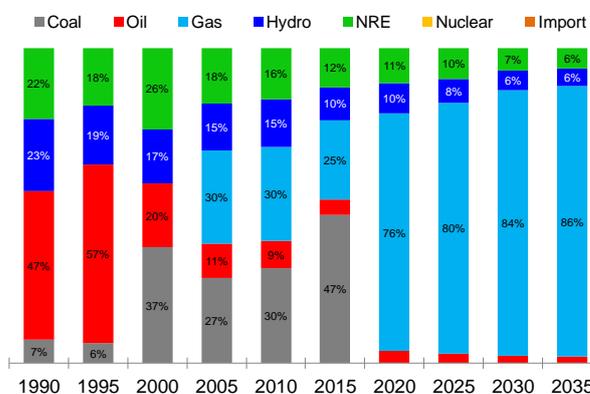
Source: APERC Analysis (2012)

An increase in natural gas production will likely spur the development of additional infrastructure, such as the expansion of natural gas fired power generation capacity, LNG (liquefied natural gas) terminals and several pipelines to extend the use of gas in other sectors, and the construction of additional CNG refueling stations for natural gas vehicles (NGVs).

In the High Gas Scenario, additional gas production will not be exported through gas pipelines. For gas pipeline exports to take place, the Philippines will need to commit to the Trans-ASEAN gas pipeline project requirements (ASCOPE, 2010).

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation in the Philippines from 2019. As shown in Figure RP9, the electricity generation from the assumed gas production will reach 161 TWh in 2035, which is 86% of the total electricity output of the economy.

Figure RP9: High Gas Scenario – Electricity Generation Mix

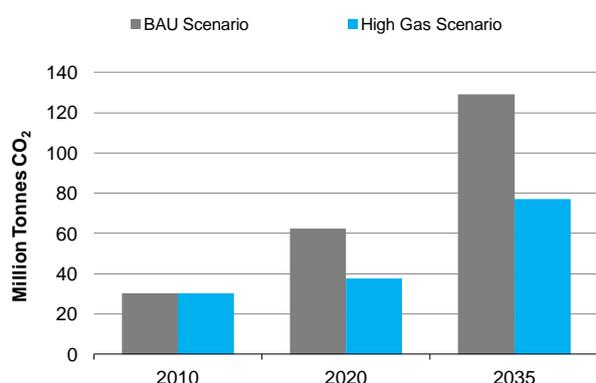


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Figure RP9 may be compared with the BAU case graph in Figure RP6. It can be seen that the gas share has reached more than 70% of the total electricity generation input by 2035, completely displacing the coal share in the Philippines electricity generation mix.

Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by 40% by 2035. This is compared to the BAU emissions level of 129 million tonnes CO<sub>2</sub> (see Figure RP10).

**Figure RP10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



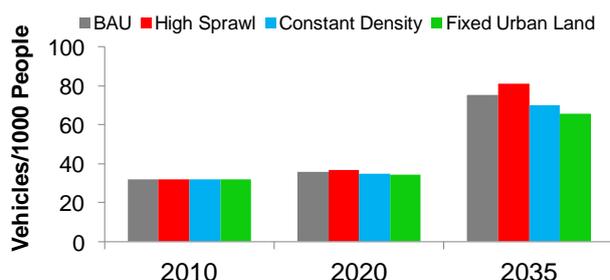
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

As urbanization in the Philippines increases rapidly in the next 25 years, so will vehicle ownership. Figure RP11 shows this change in vehicle ownership under BAU and the three alternative urban development scenarios.

**Figure RP11: Urban Development Scenarios – Vehicle Ownership**

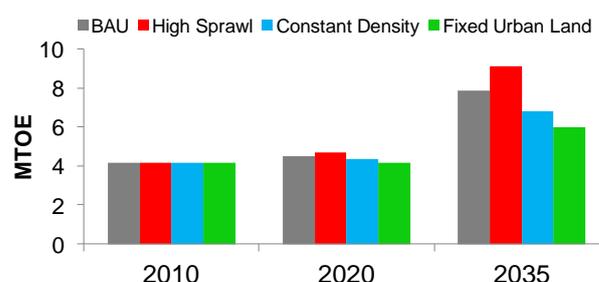


Source: APERC Analysis (2012)

Vehicle ownership in the High Sprawl scenario will be 8% higher than BAU in 2035, but 13% lower than BAU in the Fixed Urban Land scenario. This means that significant urban planning would have a direct effect on vehicle ownership in the long run, specifically in metropolitan Manila which was identified by the World Bank as one of 120 largest cities in the world.

Consequently, the oil consumption of light vehicles changed considerably under BAU and the three alternative urban development scenarios. Figure RP12 shows light vehicle oil consumption will be noticeably higher in the High Sprawl scenario, at 16% compared to BAU in 2035. On the other hand, light vehicle oil consumption in the Fixed Urban Land scenario is 24% lower than BAU by 2035, as travel distances per vehicle and vehicle ownership in more compact cities are both significantly reduced.

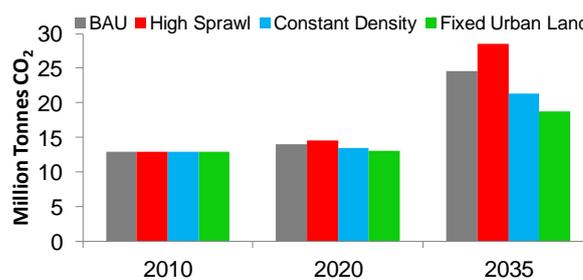
**Figure RP12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure RP13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO<sub>2</sub> emissions would be 16% higher in the High Sprawl scenario compared to BAU in 2035, and about 24% lower in the Fixed Urban Land scenario.

**Figure RP13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



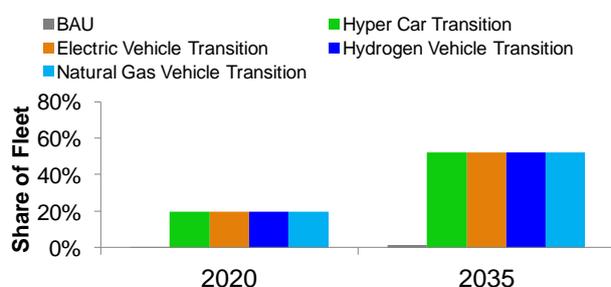
Source: APERC Analysis (2012)

### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RP14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035, the share of the alternative vehicles in the vehicle fleet is assumed to reach about 52% compared to about 1.6% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48% compared to about 98.4% in the BAU scenario.

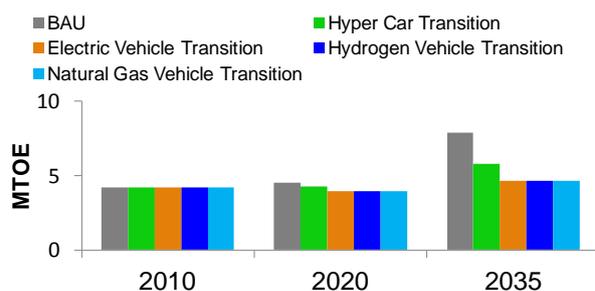
**Figure RP14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure RP15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops significantly by 41% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to the BAU scenario. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced by 26% compared to BAU by 2035, even though these highly-efficient vehicles still use oil.

**Figure RP15: Virtual Clean Car Race – Light Vehicle Oil Consumption**

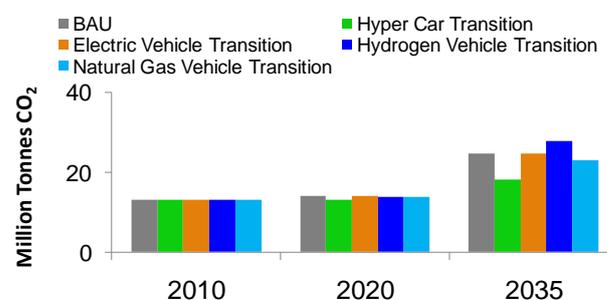


Source: APERC Analysis (2012)

Figure RP16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In the Philippines, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reduction with emissions reduced by 26% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario reduced emissions slightly, by 6% compared to BAU. The CO<sub>2</sub> emissions from the Electric Vehicle Transition scenario showed no difference compared to BAU in 2035. This may be caused by the high prevalence of coal in the electricity generation mix. The Hydrogen Vehicle Transition scenario offers no emissions reduction benefits—emissions increased by 13% compared to BAU in 2035. (To facilitate fair comparisons, the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios assumed no additional non-fossil utilization for their energy production.)

**Figure RP16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# THE RUSSIAN FEDERATION

- *Russia will maintain its position as a top global energy exporter with a more diversified mix of products exported and a more varied mix of product destinations; frontier and offshore hydrocarbon resources should replace depleting fields in the traditional oil and gas regions.*
- *Russia will need to invest heavily in oil and gas exploration and development in new frontier areas, and in the development of the accompanying energy infrastructure needed to service both existing markets in Europe and new markets in Asia–Pacific. The inflow of investment into the energy sector would be facilitated by improved investor confidence in the stability of Russian institutional arrangements and by domestic energy price liberalization.*
- *Despite the Fukushima Nuclear Accident, Russia’s nuclear energy industry remains a focus of Russia’s development: nuclear energy will take a larger share in power generation in the domestic market, while the industry will expand abroad. Russia will remain a key player in the practical implementation of improved nuclear fuel technology.*
- *Significant energy conservation and economic restructuring efforts would reduce Russia’s high level of energy intensity, allowing it to conserve its energy resources and to reduce greenhouse gas emissions.*

## ECONOMY

With a land area of more than 17 million square kilometres, the Russian Federation is geographically the world’s largest economy. It is the only APEC economy located in both Europe and Asia, and is bordered by the Arctic and the North Pacific oceans. Its terrain is characterized by broad plains west of the Urals, vast coniferous forests in Siberia, tundra along the Arctic seaboard, and uplands and mountains in the southern regions. The Russian Federation has a vast natural resource base that includes major deposits of coal, natural gas, oil and other minerals. Despite its land area advantage, the economy lacks an optimal climate for agriculture—most of its area has a continental climate, and is either too cold or too dry. Central heating is common for up to 6–8 months of the year, while cooling during the summer is not widely used.

In 1999, after a decade of economic contraction (about 40% compared to the 1990 GDP level), the Russian economy began to grow again. The recovery was triggered by a devaluation of the rouble in the aftermath of the 1998 financial crisis, and its positive impact on the economy’s competitiveness. In parallel, soaring world prices of oil and natural gas also drove the recovery.

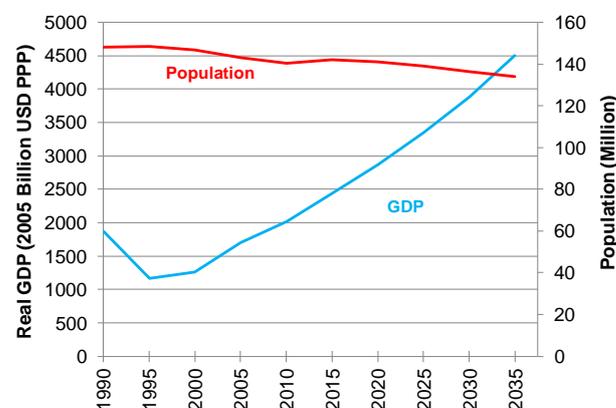
Russia’s major industries include the oil and gas production, petroleum refining, mining, iron and steel, chemicals, machinery and motor vehicles industries.

GDP increased at a rate of 4.8% per year from 2000 to 2009, reaching USD 1931 billion (in 2005 USD PPP) in 2009. Per capita income in 2009 was USD 13 712, 60% more than in 2000. Over the outlook period, Russia’s GDP is expected to

continue to grow, although at a slower average annual rate of 3.3%, to reach USD 33 600 per person (2005 USD PPP) by 2035.

Russia’s population in 2011 was around 142.8 million people. Russia’s population is projected to decline at an average annual rate of 0.2% during the outlook period and is expected to be 134 million people by 2035.

Figure *RUS9: GDP and Population*



Sources: Global Insight (2012) and APERC Analysis (2012)

The urbanization rate in 2011 was 74% and it has not changed much since 1989. Russia’s average population density of only 8.4 people per square kilometre is very low, with the majority of the population living in the European part of the economy (GKS, 2012).

Russia’s economy faces challenges due to the underdevelopment of its transport infrastructure. In particular, the current condition of Russian airports and air transport facilities provides insufficient capacity for and slows the performance of air transportation services. Further modernization of air

and rail transport is planned in connection with Russia's programs for hosting the 2014 Winter Olympic Games, the 2018 Football World Cup, and the 2020 World Expo.

The total length of Russian roads in 2009 was 983 000 kilometres (km), 80% of which was paved. The country had only 29 000 km of high-speed divided highways connecting big cities (GKS, 2012). Further development of highways will be necessary if the big cities are to be connected.

Russia has a state railway system with a total length of 83 000 km, but only some cities have high-speed train services. Almost all towns in Russia regardless of size are served by regional bus services. Subway systems have been introduced in seven of Russia's major cities, and all cities have extensive city bus systems.

Russia's pipeline transport is underdeveloped relative to the potential oil and gas supply. The total length of the pipeline system in the economy was 233 000 km in 2010, 167 000 km of which was gas pipeline, 49 000 km was oil pipeline, and 16 000 km was oil products pipeline.

Russia maintained its place in the top three automobile markets in Europe, following Germany and the UK. Vehicle production in 2011 was 1.7 million units.

## ENERGY RESOURCES AND INFRASTRUCTURE

In terms of proven reserves, the Russian Federation holds 21.4% of the world's gas, 5.3% of its oil reserves, 18.2% of its coal reserves, and about 14% of its uranium ore reserves (BP, 2012). Even more resources remain to be discovered, but the formidable obstacles of climate, terrain and distance hinder their exploitation.

The Russian energy sector is very important for the security of the global energy supply. The economy is the world's largest exporter of energy overall, and also the largest exporter of natural gas, and the second-largest exporter of oil. In addition, Russian-labelled nuclear fuel is used at 74 commercial reactors (17% of the global market) and 30 research reactors in 17 economies worldwide, and the economy provides over 40% of the world's uranium enrichment services (ME, 2012).

However, Russia's oil resources in the traditional oil producing regions are believed to be heavily depleted, with more than 50% of the economically-recoverable resources already produced. In the Urals and Volga regions, resource depletion is believed to exceed 70%. The share of remaining resources that is

hard-to-recover is constantly growing. Almost 80% of Russia's oil production comes from large fields with remaining lives of 8–10 years. Newly developed resources are often concentrated in middle-size and small-size deposits (ME, 2012). Without the development of new fields in remote areas, oil production is likely to peak at 550 million tonnes of oil equivalent (Mtoe) per year by 2020 and then decline to 400 Mtoe per year by 2035.

The refining industry in Russia includes about 30 major refineries with a total capacity for primary processing of about 254 million tonnes of crude oil per year (ME, 2012). Most of these refineries are older facilities that do not meet modern standards for energy efficiency or environmental protection. During the outlook period, the refinery industry of Russia will need to undergo modernization, with priority given to the cracking processes needed to produce the lighter fuels (such as gasoline, diesel, and jet fuel) most in demand in the market. The Russian Government's export policy favours the export of petroleum products rather than crude oil, which implies that Russia will need a large expansion of refinery capacity by 2035.

The oil sector is heavily controlled by the Russian Government and this control will increase after the state-owned Rosneft takeover of TNK-BP. The merger will create the world's largest listed oil company with a daily output of 4.6 million barrels in oil-equivalent terms (Reuters, 2012).

The gas industry of Russia has a more favourable resource situation than the oil industry. The proved natural gas resources in Russia, estimated at 44.6 trillion cubic meters (BP, 2012), should be adequate to meet both domestic market and export demands in the outlook period. Russia will continue to be a major gas supplier to Europe and planning is in progress for major export projects to serve the Asia-Pacific region.

About 79% of the gas production in 2009 was from Gazprom, a state-controlled corporation. Gazprom is also the owner of Russia's pipeline network. The company is the main gas supplier to domestic and export markets, and is the owner of most of the basic infrastructure of the Russian natural gas business.

The remaining reserves of coal in Russia amount to more than 190 billion tonnes or 18% of the world reserves. At current rates of coal consumption in the economy, these reserves will be sufficient for 800 years. Unlike the oil and gas sector, the coal industry has no large state-controlled company and is almost 100% privatized.

As of 2010, the generation of electricity and heat in Russia from thermal sources was provided by six wholesale generating companies, which operate without regard to territorial boundaries, and 14 territorial generating companies. These companies are mostly privately-owned with some state participation. RusHydro operates most of Russia's hydropower stations. Rosatom operates all Russia's nuclear energy power plants. Both of these companies are state controlled.

Russia has the world's largest and oldest district heating system with centralized heat production and distribution networks in most major cities. The system has a high number of combined heat and power (CHP) installations. Given the obsolescence of the Russian district heating infrastructure, a considerable amount of energy can be saved through relatively accessible technologies and cost-effective energy saving practices (IES, 2010).

During the outlook period, the development of Russia's electricity infrastructure will be determined by the State Program of Long Term Development of Installed Capacity and Forecast of Construction of New Capacities in the Russian Federation for the Period till 2030 (IES, 2010). Our business-as-usual projections are based primarily on this document.

## ENERGY POLICIES

The adoption of the Energy Strategy of Russia for the period up to 2020 in August 2003 (IES, 2010) was a milestone in Russia's energy sector development. The strategy identifies the economy's long-term energy policy and the mechanisms for its realization. A revised version of the strategy was adopted by the government in November 2009—the Energy Strategy of Russia for the period up to 2030, (Energy Strategy 2030) (IES, 2010). The new version of the strategy was updated to take into account the new realities and priorities in the energy sector as affected by the global recession. The strategy is a framework within which more detailed industry-oriented medium-term and short-term programs can be developed.

The strategic objective of Russia's external energy policy is to use its energy potential effectively to maximize its integration into the world's energy markets, to strengthen Russia's position in those markets, and to maximize the benefits of energy resources to the economy.

To achieve this, Russia will implement a number of measures to improve the security of domestic energy consumption and energy export obligations, and will make efficiency improvements along the entire energy supply chain. This will include the

development of new hydrocarbon provinces in remote areas and offshore. It will also include the rehabilitation, modernization and development of energy infrastructure, including the construction of additional trunk oil and gas pipelines, to enhance the economy's energy export capacity.

To better integrate Russia into world energy markets, export delivery markets will be diversified. At least 27% of Russia's total energy exports in 2030 should be delivered to the Asia-Pacific region (IES, 2010).

Despite the Fukushima Nuclear Accident, Russia's nuclear energy industry remains a focus of Russia's development. Nuclear energy will take a larger share in power generation domestically, while the industry will expand abroad. Russia will remain a key player in the practical implementation of improved nuclear fuel technology.

Despite the existing programs for renewable energy development in the Energy Strategy 2030, the economic potential of renewable energy in Russia is low. Fossil fuels in Russia are so abundant that renewables have difficulty competing.

The Energy Strategy 2030 calls for a reduction in the energy intensity of the economy by 40% by 2030 (IES, 2010). Decreasing Russia's relatively high energy intensity (about 335 tonnes of oil equivalent per million USD PPP in 2009) needs to be a main objective of Russian energy policy. Without significant progress in this area some industries may not be globally competitive, thus impeding Russia's economic development.

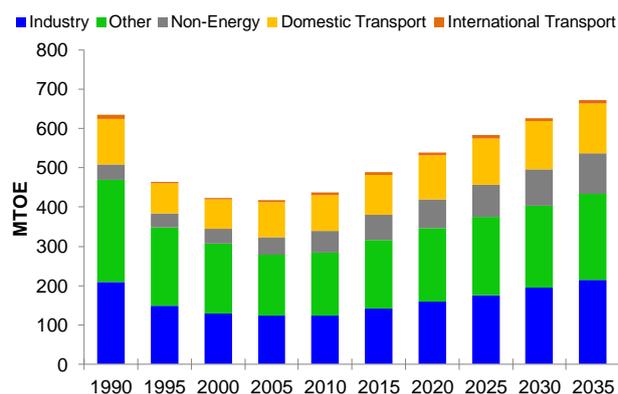
Perhaps the most important measures in the Energy Strategy 2030 are directed toward developing energy market institutions, such as fair pricing mechanisms and transparent trading principles, and making sure there is sufficient energy transportation infrastructure. State participation in the energy sector development will consist mainly of supporting innovative developments in the energy sector, as well as providing a stable institutional environment for the effective functioning of the sector (IES, 2010).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

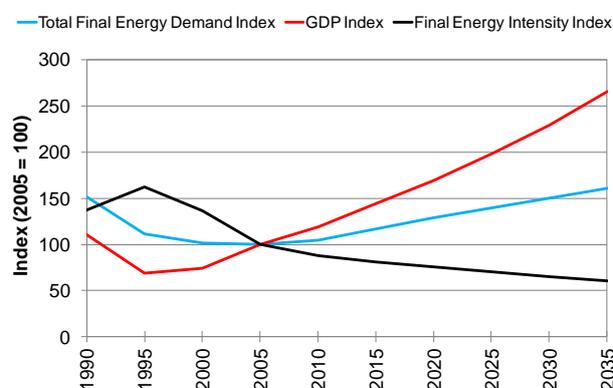
Russia's final energy demand is expected to grow at 1.7% per year over the outlook period, but will not exceed 1990 levels until after 2030. Growth is expected in all sectors. Final energy intensity is expected to decline by about 39% between 2005 and 2035.

**Figure RUS10: BAU Final Energy Demand**



Source: APERC Analysis (2012)  
 Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

**Figure RUS3: BAU Final Energy Intensity**



Source: APERC Analysis (2012)

**Industry**

Russia’s industrial energy demand is projected to grow at an average annual rate of 2.2% until 2035, with industrial growth driven by infrastructure project development in the economy. The anticipated technological retrofitting of industrial facilities is expected to contribute to improvements in energy efficiency. Moreover, a firmly implemented policy to reduce energy subsidies and link domestic energy prices with world benchmarks is expected to provide a major stimulus for energy efficiency improvements in the long term.

**Transport**

Transport energy demand increases of 1.3% annually are expected over the outlook period. Rising incomes will gradually increase passenger vehicle ownership, from around 230 per 1000 people in 2005 to about 660 per 1000 in 2035.

Road transport will continue to consume the largest share of the energy used in the transport sector over the outlook period. The improvement in

living standards and increased vehicle ownership will lead to a shift from public transport to individual passenger vehicles for commuting.

**Other**

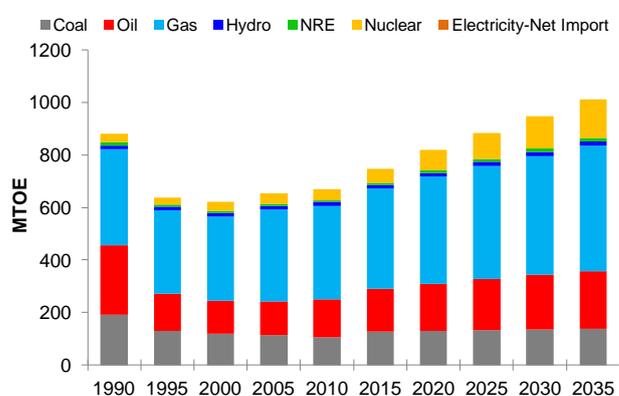
Energy consumption in the ‘other’ economic sectors (residential, commercial, and agriculture) is expected to grow by 1.2% annually over the outlook period. Due to Russia’s frigid climate, space heating accounts for a large share of this demand. Russia’s district heating systems will meet 43% of ‘other’ sector energy demand in 2035, while gas will account for another 22%. However, the current energy efficiency of heat generation and use in the residential and commercial sectors is low. A gradual shift to more energy-efficient apartment and office buildings is expected over the outlook period, encouraged by government programs. Coal and renewable energy (mainly biomass) will maintain shares of 5% and 1% respectively, mainly due to their importance in rural and remote areas.

**PRIMARY ENERGY SUPPLY**

Russia’s total primary energy supply is expected to reach 1009 Mtoe in 2035. Nuclear energy is projected to grow the fastest at an average annual rate of 5% per year, followed by new renewable energy (NRE) at 3.2%. However, NRE’s share of the total primary energy supply will still be only about 1.4% in 2035. Of the fossil fuels, oil will grow the fastest at 1.7% per year, driven by a growing transport demand. At the same time natural gas will grow by 1.2% per year, while coal will grow by 1.1% per year. Hydro output will be virtually unchanged over the outlook period.

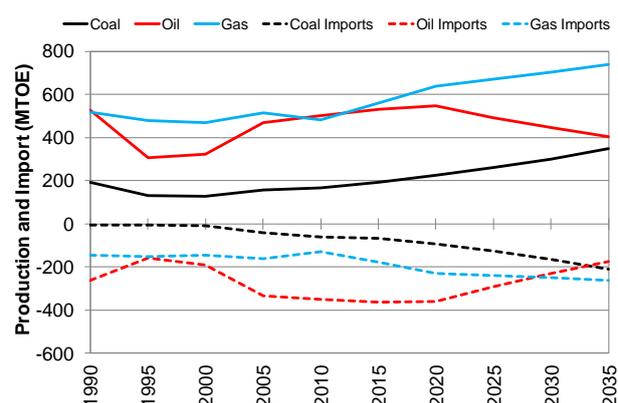
Although there are huge untapped hydro resources in the Russian Far East, their remote location and lack of local markets makes them unlikely to be developed during the outlook period.

**Figure RUS4: BAU Primary Energy Supply**



Source: APERC Analysis (2012)  
 Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure RUS5: BAU Energy Production and Net Imports



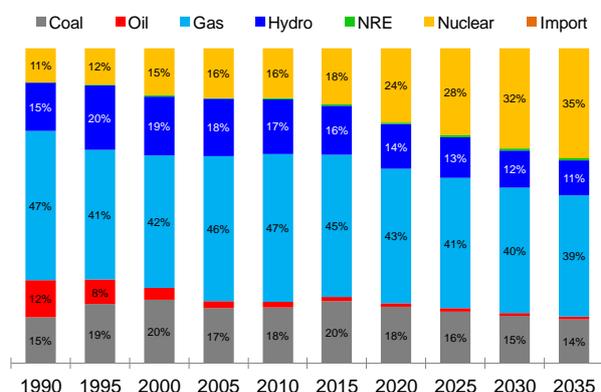
Source: APERC Analysis (2012)  
 Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Significant growth is expected in coal and gas production and exports. However, oil exports will experience a contraction over the outlook period, as domestic demand will grow and (after 2020) production may decline.

**ELECTRICITY**

Electricity demand is projected to grow at an average annual rate of 2.5%. This will require an increase in installed generation capacity from 237 GW in 2010 to 335 GW by 2035 or, in other words, the construction of more than an average 4 GW of new capacity each year within the outlook period.

Figure RUS6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
 Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

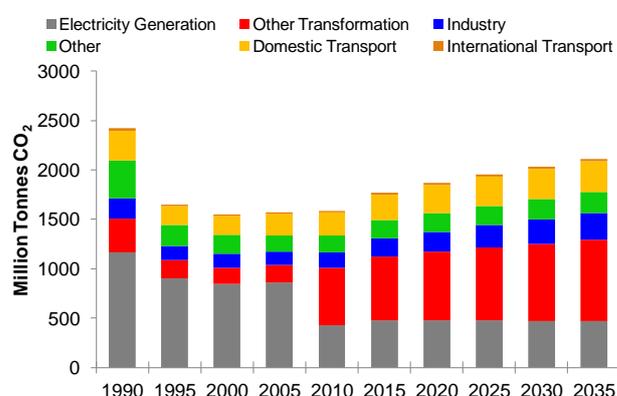
Natural gas will be the main input fuel for electricity generation in 2035 (39% share), followed by nuclear (35%), coal (14%) and hydro (11%). Electricity generation from renewable sources is expected to increase robustly at an average annual rate of 5.9%; however, its share will remain less than 1%. Petroleum products will likewise account for less than 1% of electricity generation, but they will be the major fuel for electricity generation in isolated areas,

in particular for the northern regions in the Russian Far East.

**CO<sub>2</sub> EMISSIONS**

Over the outlook period, Russia’s total CO<sub>2</sub> emissions from the energy sector are projected to reach 2113 million tonnes of CO<sub>2</sub>, which is still lower than the 1990 level of 2424 million tonnes. The emissions from electricity and district heating production will contribute 50% of the total CO<sub>2</sub> emissions in 2035. (Note, in Figure RUS7, CO<sub>2</sub> emissions from heat production shift from Electricity Generation to Other Transformation after 2010 due to data limitations.)

Figure RUS7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The major factor restraining the growth of Russia’s CO<sub>2</sub> emissions is the expected decline in energy intensity of GDP at an average annual rate of 1.7% per year (see Table RUS1 below).

Table RUS1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.9%	0.4%	-0.2%	-0.3%	-0.4%
Change in Energy Intensity of GDP	-1.3%	-3.5%	-2.0%	-2.0%	-1.7%
Change in GDP	-0.7%	3.5%	3.4%	3.3%	3.3%
Total Change	-2.9%	0.2%	1.0%	1.0%	1.2%

Source: APERC Analysis (2012)

**CHALLENGES AND IMPLICATIONS OF BAU**

Russia is one of the most energy-intensive economies in the world because of a) its frigid climate; b) the disproportionately large shares of energy-intensive industries in contrast to the much lower shares of less energy-intensive industries and services; and c) the high proportion of technologically obsolete assets within industry and the energy supply infrastructure.

In the energy sector, a refurbishment of the refining industry in Russia is urgently required to meet tightening fuel quality standards and to

drastically increase the yield of light products (which is the lowest of all APEC member economies). Russia will need to invest heavily in oil and gas exploration and development in frontier areas and offshore, and in the development of the accompanying energy infrastructure needed to service both existing markets in Europe, and new markets in Asia–Pacific. An inflow of investment into the energy sector would be facilitated by improved investor confidence in the stability of Russian institutional arrangements and by domestic energy price liberalization.

## ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

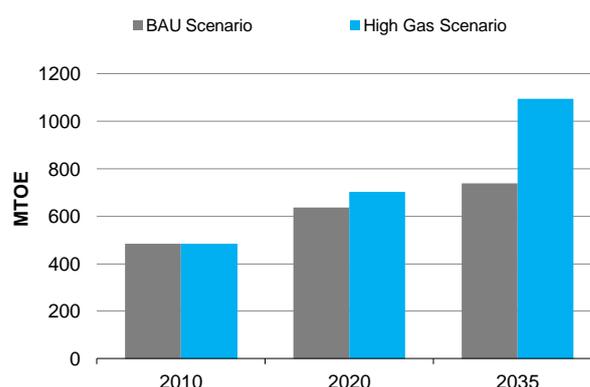
### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario production for Russia assumed the production increase shown in Figure RUS8, which equals 48% by 2035 compared with BAU. Russia has vast resources of gas in frontier areas of production like Yamal, Eastern Siberia and the Far East, which require significant investment in both production and pipeline transport infrastructure.

The High Gas Scenario would remove the restrictions on the use of the export pipeline system by private gas producing companies. This would enable greater investment in offshore gas production for liquefied natural gas (LNG) exports from both the Northern Shelf and the Far East, as well as in the onshore development of Eastern Russian gas basins for pipeline transportation to international markets, including pipeline supply to China, Korea and possibly Japan.

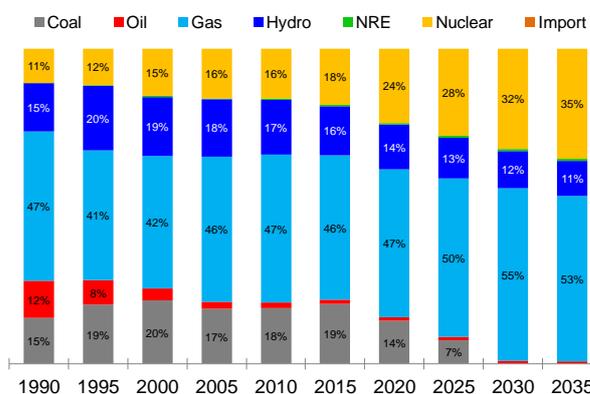
Figure RUS8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

The additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure RUS9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph in Figure RUS6. It can be seen that the gas share has increased by 14% by 2035, while the coal share has declined by a corresponding amount.

Figure RUS9: High Gas Scenario – Electricity Generation Mix

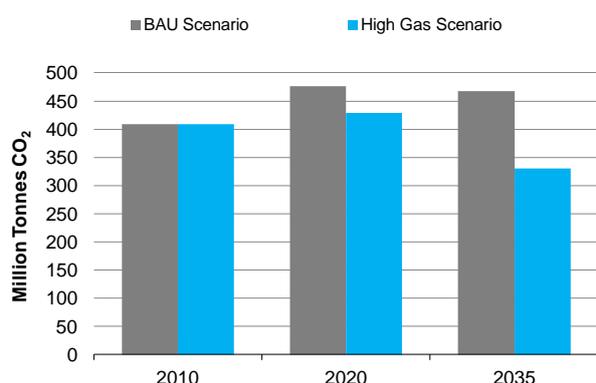


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

A higher gas share in the electricity generation mix is projected to reduce the CO<sub>2</sub> emissions in electricity generation by 10% by 2020 and by 29% by 2035, since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated. In addition to lowering CO<sub>2</sub> emissions, the High Gas Scenario would boost Russian economic growth, especially in the remote eastern regions of the economy.

**Figure RUS10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



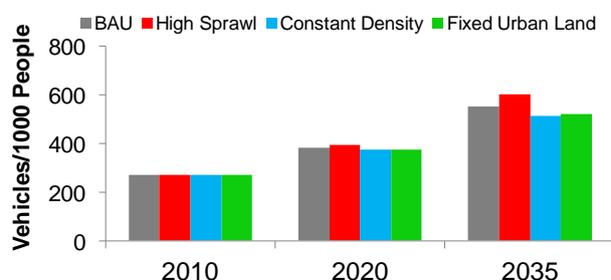
Source: APERC Analysis (2012)

**ALTERNATIVE URBAN DEVELOPMENT SCENARIOS**

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RUS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level at which the long-term saturation of vehicle ownership is reached. In the High Sprawl scenario, vehicle ownership would be about 9% higher than BAU by 2035, while in the Constant Density scenario, it would be about 7% below BAU. Note, in most economies the Fixed Urban Land scenario has a population density higher than the Constant Density scenario, and therefore a lower vehicle ownership. However, due to Russia’s expected population decline, this is not the case for Russia.

**Figure RUS11: Urban Development Scenarios – Vehicle Ownership**

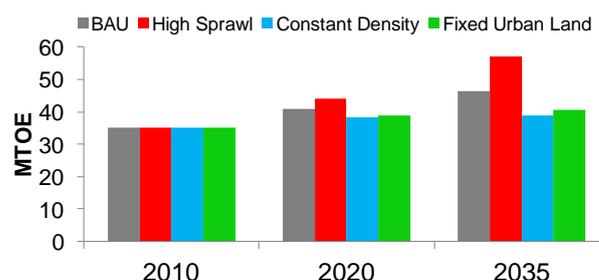


Source: APERC Analysis (2012)

Figure RUS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact on oil

consumption in the light vehicle fleet is compounded by the change in vehicle travel, since in compact cities the travel distances per vehicle are typically lower than those in sprawling cities. Consequently, in the High Sprawl scenario light vehicle oil consumption would be 23% higher than BAU, while in the Constant Density scenario it would be 16% lower than BAU.

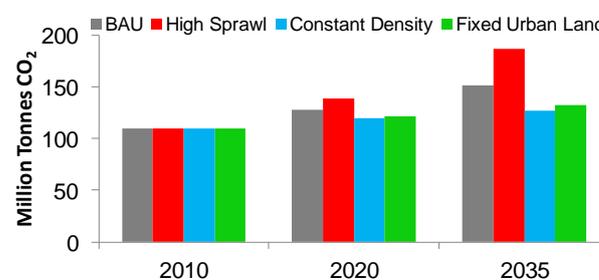
**Figure RUS12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure RUS13 shows the change in light vehicle CO<sub>2</sub> emissions in Russia under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases.

**Figure RUS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

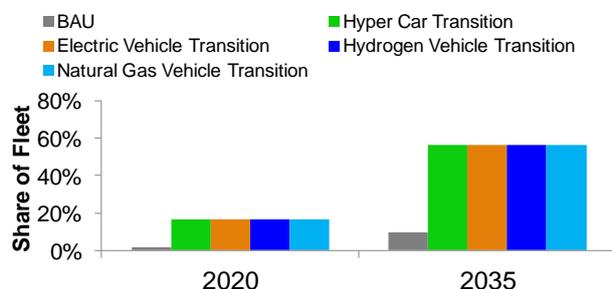
**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RUS14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 56% compared to

about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 44%, compared to about 90% in the BAU scenario.

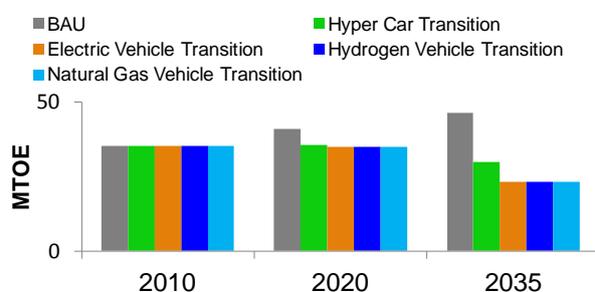
**Figure RUS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure RUS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by about 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 36% by 2035—even though these highly-efficient vehicles still use oil.

**Figure RUS15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



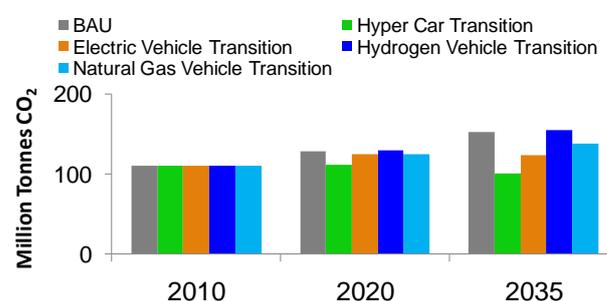
Source: APERC Analysis (2012)

Figure RUS16 shows the change in light vehicle CO<sub>2</sub> emissions in Russia under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Russia, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions

reductions, with an emissions reduction of 34% compared to BAU in 2035. The Electric Vehicle Transition scenario would reduce emissions by about 19%, reflecting our assumption that in Russia the additional electricity required by electric vehicles would be generated primarily from natural gas. The Natural Gas Vehicle Transition scenario would reduce emissions by about 9% compared to BAU. The Hydrogen Vehicle Transition scenario would increase emissions by about 2%. This is mainly due to the way hydrogen is produced—from the steam methane reforming of gas, a process which involves significant CO<sub>2</sub> emissions.

**Figure RUS16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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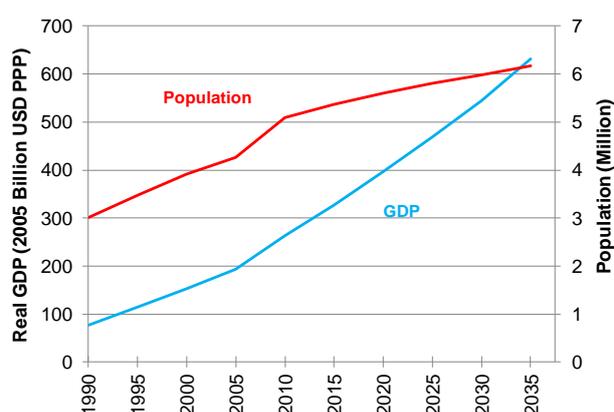
# SINGAPORE

- *Singapore's primary energy supply is projected to grow at an average annual rate of 1.1% over the outlook period, dominated by an increasing demand for oil in the transport sector.*
- *As a major logistics hub for the South-East Asia region, Singapore's international transport sector is expected to continue to dominate final energy demand. The domestic transport sector's final energy demand will continue to decline at 0.4% annually.*
- *Final energy intensity is projected to decrease by 38% from 2010 to 2035; however, the absolute amount of CO<sub>2</sub> emitted will continue to grow at 1.8% annually over the same period.*

## ECONOMY

The Republic of Singapore is an island city-state located off the southern tip of the Malay Peninsula. It is situated south of the Straits of Malacca on a major shipping route, well-located for the energy industry with regard to international oil refining and trading. It is also an emerging leader in the biotechnology industry. Its total land area is 710 square kilometres (km<sup>2</sup>) and it had a population of 4.8 million in 2009, of which 1.2 million were non-residents. The economy's population density is about 7126 persons per km<sup>2</sup>. Despite its small land area and population, Singapore is one of the most highly industrialized and urbanized economies in South-East Asia. The climate is hot and humid, with an average temperature ranging from 20 to 35 degrees Celsius and a relative humidity ranging from 80% to 90% throughout the year.

**Figure SIN1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Singapore is a mature economy. Its population is expected to grow slightly at 0.8% per year over the projection period. In 2035, the total population is expected to be about 6.2 million.

Singapore is a highly developed and vibrant free-market economy. It is the pricing centre and leading oil trading hub in Asia. In 2011, the service industry contributed 69% of GDP, while manufacturing

accounted for 27% (MTI, 2012). Most of the manufacturing output is for export. The top two exports in 2011 were electronic components and parts (31%) and refined petroleum products (26%) (MTI, 2012). Between 2010 and 2035, GDP is projected to grow moderately, at about 3.6% per year or 140% in total growth. By 2035, Singapore's GDP will grow to about USD 632 billion (in 2005 USD PPP) or about USD 102 588 per capita.

Singapore has grown into one of Asia's and the world's leading and most cost effective locations for petrochemical industries. The key for this success is Jurong Island, a collection of seven small islands that is home to three major oil refineries. Singapore is the third-largest oil and oil products trading hub in the world (EDB, 2011). It has a complex refining and petrochemical integration with a refining capacity of about 1.385 million barrels of oil per day (BP, 2012).

Domestic transport energy demand in Singapore mainly comes from road transport. The total length of roads in Singapore is 3411 km and the per capita car ownership rate is about 110 cars per 1000 people (LTA, 2012b). Singapore has been motivated to reduce car ownership and to encourage people to use public transport. Private car ownership has been moderated through the use of various measures, such as mandatory car ownership quotas by limiting the number of vehicle ownership certificates; electronic road pricing on congested roads; a green vehicle rebate to encourage more fuel-efficient vehicles; and trials of green technologies such as diesel hybrid buses and electric vehicles.

Rail transport plays a significant role in the economy. The total length of the mass rapid transit (MRT) and the light rail transit (LRT) systems as of 2011 is 138 km and they handle an average daily ridership of about 2.4 million passengers (LTA, 2012b). The Land Transport Authority of Singapore has targets to expand the rail network to 278 km by 2020, and to increase the rapid transit system (RTS) density from 31 km per million population to 51 km per million population (LTA, 2012a).

Singapore is the busiest sea port in the world in terms of shipping tonnage, with some 120 000 vessel calls annually, and the economy is connected to more than 600 ports in over 120 countries worldwide (MPA, 2009). Singapore's Changi Airport is ranked the seventh busiest international airport. Each week, more than 6200 flights land or depart from Changi Airport, with more than 46.5 million passengers passing through the airport in 2011 (CAG, 2012).

## ENERGY RESOURCES AND INFRASTRUCTURE

Singapore has negligible indigenous energy resources, either in fossil fuels or in alternative energy sources. Singapore imports nearly all the fuel it requires for its energy needs, except for a small portion of energy produced from incinerating municipal waste. In 2009, 146.1 Mtoe (million tonnes of oil equivalent) of energy products were imported, mainly consisting of petroleum products, crude oil and natural gas liquids (NGLs), and natural gas that accounted for 61.8%, 33.2% and 5% of energy imports, respectively (EMA, 2011, p. 10). Singapore exported 84 Mtoe of energy products in the same year, consisting mostly of refined petroleum products (EMA, 2011, p. 10).

Oil is mainly imported from the Middle East, and it is mainly used by the transport and industry sectors. Natural gas is imported from Malaysia and Indonesia. Imported natural gas is transported via four offshore pipelines—two pipelines from Indonesia (9.2 million standard cubic metres per day from West Natuna and 9.9 million standard cubic metres per day from South Sumatra) and two pipelines from Malaysia (supplying 4.2 and 2.8 million standard cubic metres per day).

About 80% of Singapore's electricity demand is produced from natural gas as fuel (EMA, 2011, p. 14). As Singapore's demand for gas is expected to exceed supply via pipeline in the near future, Singapore is planning to import LNG (liquefied natural gas). The construction of Singapore's first LNG receiving terminal began in March 2010 on Jurong Island (EMA, 2010). The LNG receiving terminal is expected to begin operations in the second quarter of 2013. It will have an initial capacity of 3.5 million tonnes per year, which will be increased to 6 million tonnes per year by the end of 2013 (EMA, 2010).

Singapore has limited land area and lacks the natural endowments necessary to make use of non-fossil energy alternatives to meet its needs. As such, Singapore is recognized as 'alternative energy-disadvantaged' under the United Nations Framework

Convention on Climate Change (UNFCCC) (NEA, 2010, p. 11). The economy does not have any hydro or geothermal resources, and average wind speeds are too low to generate power efficiently or economically. Wave and tidal technologies have limited application as much of Singapore's sea space is used for ports, anchorage and shipping lanes.

Despite these disadvantages, Singapore is keen to adopt renewable energy solutions to improve its energy security. To this end, the Singapore Government has begun to harness energy from solar photovoltaic (PV), waste incineration and bio-gas for power generation. By 2010, 3% of Singapore's electricity generation came from these renewable resources (EMA, 2011, p. 14).

Singapore does not have a nuclear energy industry. However, nuclear energy is considered by the government as a long-term energy supply option for Singapore 20–30 years down the road.

## ENERGY POLICIES

The Singapore Government published the National Energy Policy Report in 2007. The report contains a robust national energy framework aimed at meeting the economy's objectives for economic competitiveness, energy security and environmental sustainability (MTI, 2007). Under the policy, the economy has defined the following key energy strategies:

1. Promote competitive energy markets
2. Diversify energy supplies
3. Improve energy efficiency
4. Build an energy industry and invest in energy research and development
5. Promote greater regional and international cooperation
6. Develop a whole-of-government approach.

In 2009, Singapore voluntarily committed to a 16% reduction in emissions below 2020 business-as-usual (BAU) levels, contingent on a legally binding global agreement on climate change in which all countries implement their commitments in good faith (NEA, 2010, p. 37). The Sustainable Singapore Blueprint (SSB) was developed based on this commitment. It details several other energy goals to be achieved by 2030, including reducing energy intensity (per SGD GDP) by 35% from 2005 levels; setting a cap for sulphur dioxide (SO<sub>2</sub>) levels at 15 micrograms per cubic metre (µg/m<sup>3</sup>); and improving the recycling rate to 70% (NEA, 2010, p. 5).

The Energy Market Authority (EMA), under the Ministry for Trade and Industry, is mandated to regulate the electricity and piped gas industries and the district cooling services in designated areas. Both the electricity and gas industries have been liberalised—the electricity industry since 1995 and the gas industry since 2008. The gas pipeline network is owned and operated by PowerGas Ltd.

The electricity industry is divided into contestable and non-contestable sectors. The non-contestable consumers constitute 25% of the total electricity sales in Singapore and purchase their electricity from SP Services Ltd at a regulated tariff. Generation companies compete to sell electricity to the National Electricity Market of Singapore (NEMS), established in January 2003. Electricity is then transmitted through the grid network operated by the EMA.

The EMA has launched several initiatives to spur the development of more diverse and sustainable energy solutions. These initiatives include setting up the Electric Vehicles Test Bed for electric vehicles (EVs) that provides an open platform for industry players to test EV prototypes and vehicle charging technologies; setting up the Pulau Ibin Micro-grid Test Bed to assess the feasibility and scalability of electricity supply from a micro-grid infrastructure using an intermittent renewable energy supply; and the Intelligent Energy System (IES) pilot to test and evaluate new smart grid applications and technologies. These initiatives will transform Singapore's energy landscape into something more dynamic, and will enable the economy to spearhead the adoption of new, smart technologies in the region.

Energy efficiency is an integral part of Singapore's energy policy and the Energy Efficiency Programme Office (E<sup>2</sup>PO) was established to promote and facilitate the adoption of energy efficiency in Singapore. E<sup>2</sup>PO focuses on a sectoral approach to energy efficiency, targeting five sectors namely power generation, industry, transport, building and household. The following outlines some of the ongoing and planned programmes:

- *Power generation sector.* Market competition in Singapore's electricity industry acts as a natural incentive for power generation companies to be energy efficient. The government aims to further maximize efficiency in this sector by encouraging more co-generation and tri-generation facilities—these facilities produce two to three utilities (like electricity, steam, chilled water) from a single integrated system.
- *Industry sector.* A SGD 10 million (USD 8.1 million) Energy Efficiency Improvement

Assistance Scheme (EASe) was launched in 2005 to provide financial assistance to Singapore's companies to conduct energy appraisals for buildings and industrial facilities. To equip facility owners and technical staff with the necessary knowledge and skills to manage energy services within their facilities, a Singapore Certified Energy Manager Training Grant was introduced. Investment in energy efficient equipment is encouraged through the Investment Allowance Scheme (IAS).

- *Transport sector.* The Fuel Economy Labelling Scheme (FELS) was launched to provide buyers of passenger cars and light goods vehicles with fuel economy information at point of sale. The Green Vehicle Rebate (GVR) encourages the purchase of green vehicles by providing green passenger cars and electric motorcycle rebates of 40% and 10% of the open market prices. The Vehicle Quota System (VQS) and Electronic Road Pricing (ERP), on the other hand, limit car ownership and usage, and promote the use of public transport.
- *Building sector.* The Energy Smart Labels are awarded to existing buildings with good energy performances. The Green Mark Buildings rating system evaluates new buildings on their environmental impact and performance, and awards Certified, Gold, GoldPlus or Platinum ratings depending on the points scored on a set of criteria. The EASe scheme for the industry sector also applies to buildings.
- *Household sector.* To encourage energy efficient purchases, the Mandatory Energy Labelling Scheme (MELS) and the Minimum Energy Performance Standards (MEPS) were introduced for energy intensive appliances like air conditioners and refrigerators. In 2008, the government launched the 10% Energy Challenge, a national public awareness campaign challenging households to reduce their electricity consumption by at least 10% by adopting simple energy saving habits.

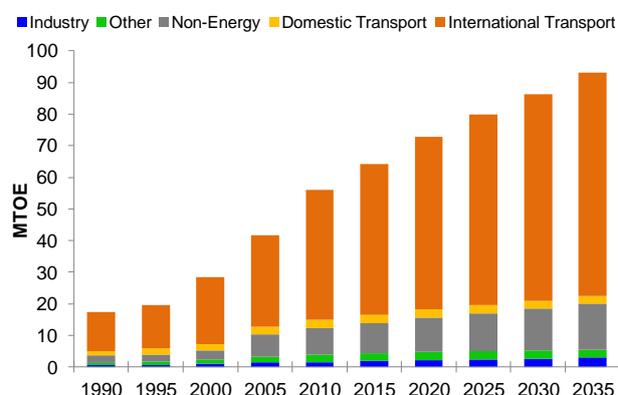
## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at 1.6% per year over the outlook period, from about 56 Mtoe in 2010 to over 22.5 Mtoe by 2035 (This figure includes demand from international transport sector). If we discount demand from international transport sector, by 2035 over 75% of the final energy demand will be for oil, followed by electricity and natural gas. Demand for

new renewable energy (NRE) will grow the fastest at 5.3% annually; however the share for NRE in 2035 will still be comparatively low at 0.3%.

**Figure SIN2: BAU Final Energy Demand**

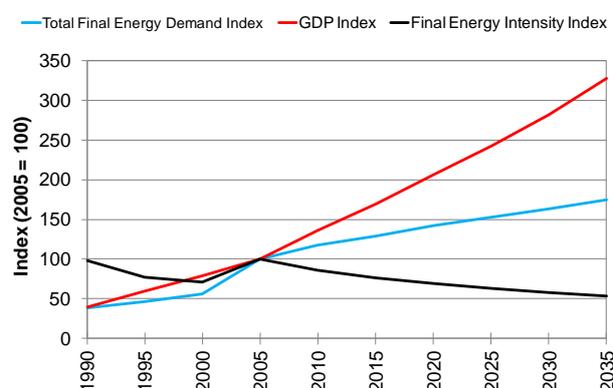


Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As a major trading and oil refining hub, international transport and the non-energy sector dominate Singapore’s final energy demand, taking up 76% and 16% respectively of the total final energy demand by 2035. With the exception of the domestic transport sector, all sectors will show growth from 2010 to 2035. Domestic transport sector demand is expected to decline at the rate of 0.4% annually from 2010 to 2035; this can be attributed to the comprehensive energy efficiency measures expected in the transport sector.

For Singapore, final energy intensity is likely to decline by 47% between 2005 and 2035. Please note that for the purpose of calculating final energy intensity, international transport is excluded so only domestic energy demand is considered.

**Figure SIN3: BAU Final Energy Intensity**



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 2.5%

until 2035, reflecting the growth of Singapore’s industries. Industrial electricity demand will consistently account for the largest share from 2010 to 2035 at about 65%, while industrial gas demand will see the highest growth, by 87% to 0.8 Mtoe by 2035.

### Transport

Domestic transport demand is projected to decrease from 2010 to 2035 by 0.4% annually, to 2.5 Mtoe by 2035. The oil share in total domestic transport demand will decline from 96% in 2010 to 88% by 2035. The rest will be taken up by natural gas (5%), electricity (4%) and bio-fuel (3%). With less oil combustion, energy intensity for this sector will decrease by over 60% from 2010 to 2035.

This positive trend could probably be attributed to the many initiatives the government has put in place to reduce and diversify energy use in the transport sector, particularly its initiatives to promote the use of alternative vehicles and public transport.

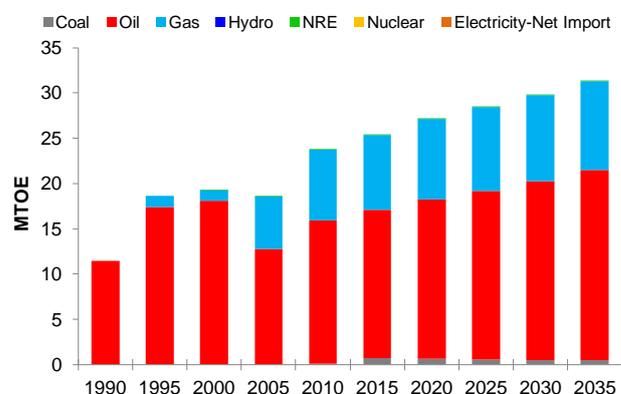
### Other

Energy demand in the ‘other’ sector, which includes residential, commercial, agricultural, and construction demand, is expected to grow at 0.5% per year over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for about 90% of ‘other’ energy consumption from 2010 to 2035.

### PRIMARY ENERGY SUPPLY

Singapore’s primary energy supply is projected to grow at an annual rate of 1.1% per year over the projection period, from 24 Mtoe in 2010 to 31 Mtoe by 2035.

**Figure SIN4: BAU Primary Energy Supply**



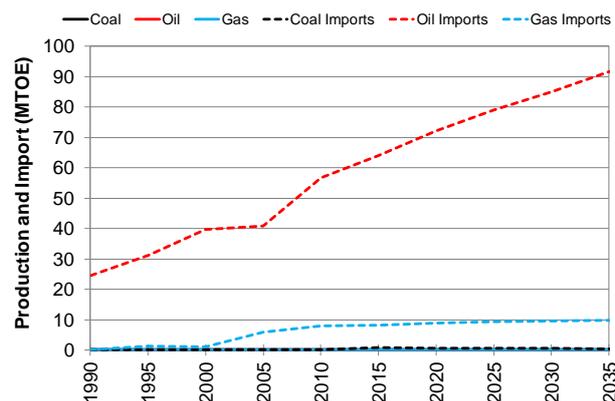
Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Oil will dominate the primary energy mix accounting for 64–68% of primary energy supply from 2010 to 2035, most likely to meet the demand

of the international transport sector. Natural gas, coal, and NRE will constitute the remaining share of supply at 31%, 1.4% and 0.4% respectively by 2035.

Singapore’s first 160 MW biomass clean coal (BMCC) co-generation plant, developed as part of the Tembusu multi-utilities complex on Jurong Island, is expected to begin operations by the end of 2012. This will contribute to the introduction of coal fuel and biomass into the primary energy supply mix from 2012 onwards.

Figure SIN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

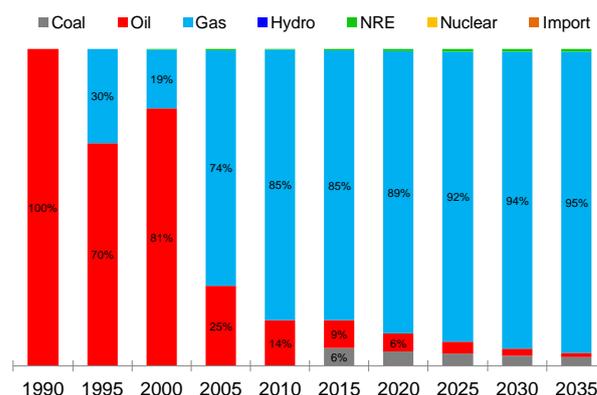
Singapore has negligible indigenous energy resources, either in fossil fuels or in alternative energy sources. The economy imports nearly all the fuels it requires for its energy needs, particularly oil. The supply of imported gas via pipelines is likely to remain constant. The future demand for natural gas (for electricity generation) will probably be supplied by imported LNG once the LNG import terminal on Jurong Island begins operations in 2013.

**ELECTRICITY**

Singapore’s final electricity demand is projected to increase slightly by 38% from 37 TWh in 2010 to 51 TWh by 2035. Singapore is a mature economy that employs various incentives and regulations to promote energy efficiency measures; hence the small growth compared to its developing neighbours Malaysia (103%) and Indonesia (293%).

On the supply side, Singapore will begin to diversify its electricity generation mix from 2012 with the introduction of coal and NRE (in the form of solar and biomass) into the supply mix. However, natural gas will continue to be the dominant fuel throughout the outlook period.

Figure SIN6: BAU Electricity Generation Mix

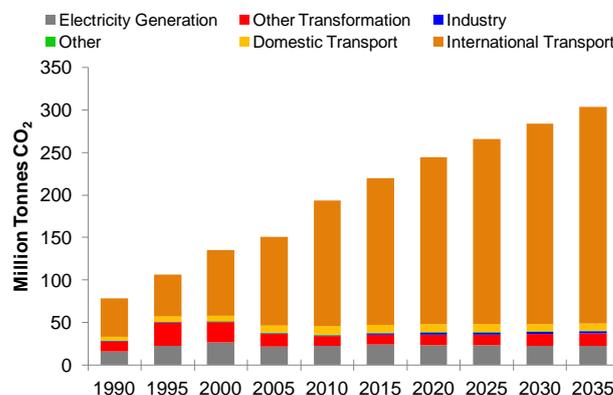


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

**CO<sub>2</sub> EMISSIONS**

Over the outlook period Singapore’s total CO<sub>2</sub> emissions from fuel combustion are projected to increase 1.8% annually to reach 304 million tonnes of CO<sub>2</sub> by 2035, compared to 194 million tonnes of CO<sub>2</sub> in 2010. While the international transport sector will continue to be the largest contributor to CO<sub>2</sub> emissions in Singapore, emissions from the domestic transport sector will show a 14% emissions reduction from 2010 to 2035. The industry sector will show the highest growth rate at 2.5% annually from 2010 to 2035.

Figure SIN7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table SIN1 below suggests that, from 2010 to 2035, the total change in carbon emissions is affected by Singapore’s GDP growth, offset by the reduction in energy intensity (energy efficiency) and CO<sub>2</sub> intensity of energy (fuel switching).

**Table SIN1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion**

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.2%	-1.2%	-0.2%	-0.2%	0.0%
Change in Energy Intensity of GDP	-1.6%	0.1%	-1.3%	-1.4%	-1.7%
Change in GDP	6.4%	6.4%	4.2%	4.0%	3.6%
Total Change	4.4%	5.2%	2.6%	2.4%	1.8%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

As a small economy without any significant energy resources, Singapore is totally dependent on imported energy to meet its energy needs. Energy security is a main challenge, along with economic competitiveness and environmental sustainability.

Singapore continues to take various measures to meet these challenges, intensifying its efforts in energy diversification to enhance the security of supply, and energy efficiency to reduce demand and mitigate carbon emissions. Research and development is another important part of Singapore’s energy strategy. The economy is likely to capitalize on its strength in this area to develop innovative and sustainable solutions to address Singapore’s energy needs.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

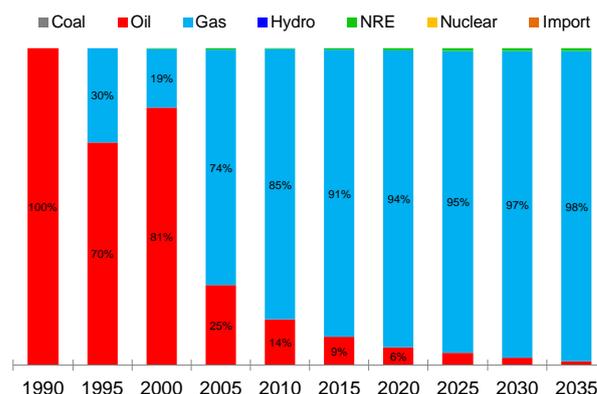
#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced. Singapore does not produce natural gas, so Figure SIN8 is not included for this economy.

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. Singapore currently imports natural gas from Malaysia and Indonesia via pipelines, and will soon import LNG through the new LNG import terminal on Jurong Island. In a situation where there is more gas available, Singapore will likely choose to import additional gas via LNG.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure SIN9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph shown in Figure SIN6. It can be seen that the gas share has increased by 3% by 2035, while the coal share has declined by an equal amount.

**Figure SIN9: High Gas Scenario – Electricity Generation Mix**

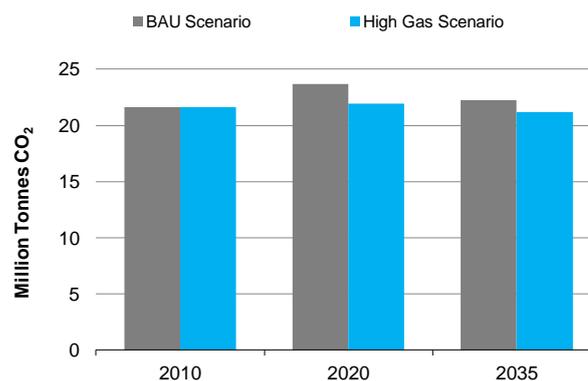


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by 5% by 2035. Figure SIN10 shows this CO<sub>2</sub> emissions reduction.

**Figure SIN10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



Source: APERC Analysis (2012)

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

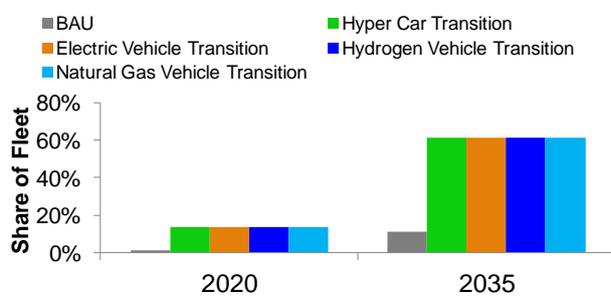
The Alternative Urban Development Scenarios are not performed for Singapore since it is already a compact city with high urban density and low energy consumption. Therefore, Figures SIN11–SIN13 are not included here.

### VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure SIN14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 62% compared to about 11% in BAU. The share of conventional vehicles in the fleet is thus only about 38%, compared to about 89% in the BAU scenario.

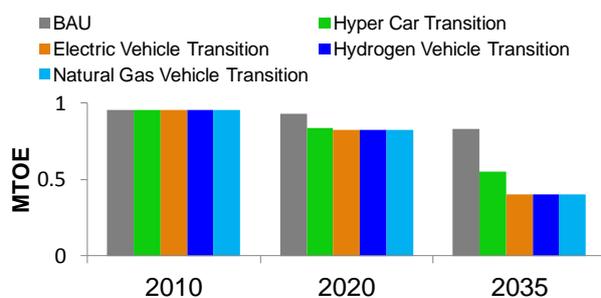
Figure SIN14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure SIN15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly-efficient vehicles still use oil.

Figure SIN15: Virtual Clean Car Race – Light Vehicle Oil Consumption



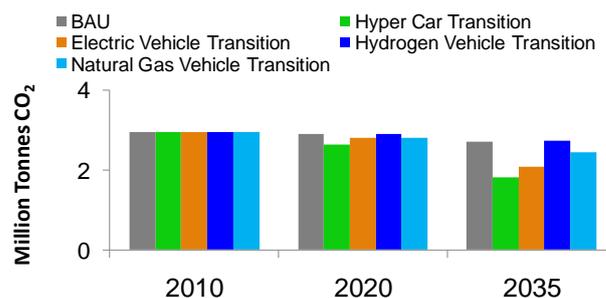
Source: APERC Analysis (2012)

Figure SIN16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Singapore, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions reductions, with an emissions reduction of 33% compared to BAU in 2035. Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels; namely electricity for electric vehicles, hydrogen for hydrogen vehicles and natural gas for natural gas vehicles. In Singapore, electricity generation mostly comes from thermal combustion; thus additional demand for electricity and hydrogen generation would produce more CO<sub>2</sub> emissions, offsetting some of the benefits gained from oil replacement.

The Electric Vehicle Transition, Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer less emissions reductions (23%, 10% and 0% respectively).

Figure SIN16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions



Source: APERC Analysis (2012)

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# CHINESE TAIPEI

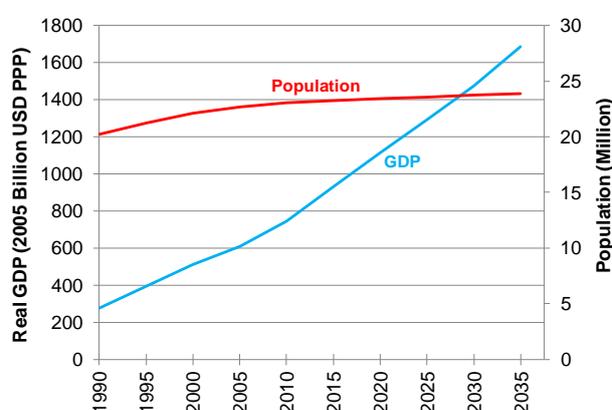
- *Chinese Taipei's primary energy supply is projected to grow at an average annual rate of 0.4% over the outlook period; this is due mainly to demand growth in the 'other' sector which consists of the residential, commercial, and agricultural sectors.*
- *The economy aims to reduce its total CO<sub>2</sub> emissions by changing its energy mix, specifically increasing imports of natural gas, developing renewable energy sources, and employing cleaner coal technologies and carbon capture and storage (CCS).*
- *The Renewable Energy Development Act (2009) has been introduced to speed up the development of clean energy. The share of electricity generated from renewable energy sources is expected to rise from 1% of total electricity generation in 2005 to about 8% in 2025.*
- *Government policy goals in the energy sector include reducing the economy's energy intensity by 50% by 2025 (from 2005 levels) and returning CO<sub>2</sub> emissions to 2000 levels by 2025.*

## ECONOMY

Chinese Taipei is located in the middle of a chain of islands stretching from Japan in the north to the Philippines in the south. Its position, just 160 kilometres off the southeastern coast of China, makes it a natural gateway to East Asia.

The economy is made up of the islands of Taiwan, Penghu, Kinmen, Matsu, and several islets, with a total area of about 36 188 square kilometres. Only one-quarter of the land is arable, although the subtropical climate permits multi-cropping of rice and year-round cultivation of fruit and vegetables.

**Figure CT11: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

The population of Chinese Taipei is expected to increase at a slow average annual rate of 0.15% over the outlook period, from 23.04 million in 2010 to 23.9 million in 2035. However, according to the economy's own projections, negative population growth is likely by the 2020s, due to a low birth rate and negative net immigration (CEPD, 2012a).

Chinese Taipei's GDP is expected to grow at an average annual rate of 3.3% over the outlook period; however, the projection also shows that the rate of growth in GDP is expected to slow during the

period. The projected average rate for 2010–2035 is below the high average annual GDP growth rate of 4.7% in the 1990–2009 period, indicating that Chinese Taipei is becoming a highly developed economy. At the same time, GDP per person is projected to grow from USD 29 200 in 2009 to USD 70 611 by 2035, at an average annual growth rate at 3.2%. These GDP per capita figures also show a gradually decreasing trend when compared with the 1990–2009 period.

The rapid economic development since 2000 has resulted in substantial changes to the economic structure of Chinese Taipei, with the emphasis moving from industrial production to the service sector. In 2010, 67.1% of domestic production was in the service sector, with industry accounting for 31.3% and agriculture 1.6% (CEPD, 2012b). In comparison, in 1990 services made up 57.0% of production, and industry 38.9%. This gradual change in the economic structure over last two decades is expected to continue in the future. Future challenges will include further restructuring of the economy's traditional manufacturing industry into high-value-added industry, and expansion of the information and communication technology (ICT) and service industry sectors.

Chinese Taipei's main industries are electronics, petrochemicals, metals, and mechanical equipment. Within the manufacturing sector itself there has also been structural change, from energy-intensive industries to industries that are non-energy-intensive. The non-energy-intensive and high-tech industries now produce the majority of exports: electronic products, machinery, electrical equipment, information and communication products, and precision instruments accounted for about 52.1% of the economy's total exports in 2010 (IDB, 2011).

Chinese Taipei imports almost all the crude oil required for its refining and petrochemical industries.

The economy's total refining capacity has reached 1.26 million barrels per day, which exceeds the domestic demand for petroleum products—Chinese Taipei is a net exporter of refined petroleum products (BOE, 2012a).

The industry sector (including non-energy use) is the single greatest consumer of energy in the economy, accounting for about 64% of final demand in 2010. It was followed by domestic transportation at 18%, residential at 9% and commercial at 6%; agriculture and non-specified demand account for the balance. Energy use in industry is dominated by chemical and petrochemical processing (about 37% in 2010), while iron and steel production used about 15%.

Chinese Taipei has developed a comprehensive domestic transport system including two freeways and one high-speed railway running north–south across the island of Taiwan. Transport sector energy consumption totalled about 15.6 Mtoe in 2010—most of this was used in road transportation (about 11.3 Mtoe or 73%), with international aviation using about 2.0 Mtoe (13%). Chinese Taipei has been striving to reduce its automobile dependency (in 2010 there were about 5.9 million passenger cars in the economy) and to encourage the use of public transport (CEPD, 2012b). The public transport systems include a high-speed rail system, which runs 345 km from Taipei to Kaohsiung, and rail rapid transit systems in Taipei city (110 km), in Kaohsiung city (39 km), and in Hsinchu city (11 km) (MOTC, 2012). There are plans for construction of further rail rapid transit systems in urban centres, including in Taipei, Taichung and Kaohsiung.

The policies encouraging a shift to public transport have been successful in Taipei city, with the daily ridership increasing at an average annual rate of 18.74% from 1998 to 2011 (MOTC, 2012). In 2011 the Taipei Metro served, on average, 1.55 million passengers per day (IRTC, 2012). In 2010 the total number of registered vehicles (including heavy vehicles) was around 7.05 million, with 78% of those domestically produced (TTVMA, 2012). Between 2002 and 2011, the total number of vehicles increased only 19.1%, with motorcycles increasing by 26.7% over that period (MOTC, 2012).

As the majority of the population is concentrated in major cities, electricity is the main source of energy for almost all homes; the electricity demand has grown at an average annual rate of 4.2% from 1995 to 2010. Air conditioning in the summer season is a major source of residential electricity demand.

## ENERGY RESOURCES AND INFRASTRUCTURE

Chinese Taipei has very limited indigenous energy resources: domestic natural gas provides just 0.1% of the economy's primary supply, while hydro provides 0.3%, and geothermal, solar and wind power combined provide 0.2%.

Instead, Chinese Taipei relies on imports for most of its energy requirements and is a net importer of fossil fuels—in 2010 its import dependency was 99%. On an energy equivalent basis, oil formed the biggest part of the imports, at about 50% (coming mainly from Saudi Arabia, Kuwait and Iran); coal made up 38% (mainly from Australia, Indonesia and China), while imported LNG, mainly from Indonesia and Malaysia, made up 12%.

Two LNG terminals with a total capacity of 10.44 million tonnes were operating in Chinese Taipei in 2010. More LNG terminals are planned to meet the economy's projected growth in demand for natural gas. In addition to LNG terminals, Chinese Taipei has an extensive gas transmission and distribution network. This infrastructure means 44.1% of the economy's population has direct natural gas supply (BOE, 2012b).

In 2012 when this outlook was prepared, there were three nuclear power plants in Chinese Taipei, each with two units, creating a total installed capacity of 5144 MW. A fourth nuclear power plant (also with two units) is under construction; these two new units are scheduled to begin commercial operation in 2014 and 2016, adding 1350 MW of capacity per unit (AEC, 2012). A revision of nuclear energy policy following the Fukushima accident in Japan means older plant decommissioning will begin when the fourth plant becomes operational—see 'Energy Policies' below.

Chinese Taipei's total electricity generation in 2010 was 247 TWh (IPC, 2011). Fossil fuels are the basis of 78% of all electricity generated: coal provides about 52%, LNG 22%, and oil 4%. Nuclear power accounted for about 18% of total electricity generation in 2010, with the remainder coming from hydro and new renewable energy sources.

## ENERGY POLICIES

Chinese Taipei's Energy Commission, which was established in 1979 under the Ministry of Economic Affairs (MOEA), became the Bureau of Energy in 2004. The Bureau is responsible for formulating and implementing the economy's energy policy. Policy development since 2008 has included the establishment of a suite of energy-related regulations

defining the rules for markets in renewable energy, petroleum products, natural gas, and electricity. The aim is to create a better energy business environment.

The fundamental goal of Chinese Taipei's energy policy is to promote energy security, supported by secure imports of oil, natural gas and coal as well as the development of domestic energy resources including nuclear, fossil fuels, and new renewable energy sources.

On 5 June 2008, the Ministry of Economic Affairs released the *Framework of Taiwan's Sustainable Energy Policy* (BOE, 2012c). This presents a 'win-win-win' solution for energy, the environment and the economy. The framework addresses the constraints that Chinese Taipei faces in terms of its insufficient natural resources and limited environmental carrying capacity. It states that sustainable energy policies should support the efficient use of the economy's limited energy resources, the development of clean energy, and the security of energy supply. The framework establishes three goals:

- Reductions in energy intensity from 2005 levels—by 20% by 2015 and by 50% by 2025.
- Reductions in total CO<sub>2</sub> emissions, so that total emissions return to the 2008 level between 2016 and 2020, and are further reduced to the 2000 level by 2025; at the same time, the share of low-carbon energy in the electricity generation system will be increased from the current 40% to 55% by 2025.
- Secure and stable energy supply, achieved by building a secure energy supply system to meet economic development goals, specifically 6% average annual GDP growth rate from 2008 to 2012, and USD 30 000 per capita income by 2015.

To achieve these goals, Chinese Taipei has set these energy conservation targets and strategies:

- *Industry sector*: raise boiler efficiency, expand cogeneration, and increase the share of high-value-added industries
- *Power sector*: replace old coal-fired and gas-fired units with high-efficiency generating units and reduce line losses by improving power dispatch and transmission facilities
- *Transportation sector*: raise the fuel efficiency standard for private vehicles by 25% (compared to 2005 levels) by 2015
- *Residential and commercial sectors*: raise appliance efficiency standards to a range of 10% to 70% in 2011; completely eliminate incandescent lights and replace them with LED lighting by 2025.

In terms of electricity supply, Chinese Taipei aims to have an electricity supply that provides a reserve capacity of 16%, based on peak demand. Until 1998, the government-owned Taiwan Power Company (TPC) was the only power company operating in Chinese Taipei. Because of environmental issues and a complex official approval process, the construction of new power plants by TPC fell behind schedule; this resulted in the total reserve capacity falling below the government requirement between 1990 and 2004. Reserve capacity remained under 8% between 1990 and 1996. In order to stabilize the power supply, Chinese Taipei's electricity market was opened to independent power producers (IPPs) in 1998. TPC contracted with IPPs for a capacity of around 5000 MW to lift the target reserve capacity above 16%—a target which has been achieved since 2004 (TPC, 2011). In 2010, the total IPP capacity was 7707 MW, about 18% of the economy's total. The power produced by the IPPs is currently sold to TPC for distribution through TPC's transmission lines.

In another move to avoid electricity shortages, TPC was required to adopt new management systems, including demand-side control, increasing the purchase of electricity from cogeneration systems, providing price incentives for electricity demand reduction and other energy conservation measures. The Ministry of Economic Affairs has also announced it will open a fifth round of bidding to IPPs if the reserve capacity falls below 16% in the future.

In line with the government's overall goal of privatizing TPC and promoting the liberalization of the domestic power market, the Electricity Act was approved by Chinese Taipei's Legislative Yuan in early 2011. This enables IPPs to build and invest in transmission and distribution facilities. In addition, IPPs will be able to sell power to consumers directly, which means the market structure will no longer be a monopoly.

Following the 2011 Fukushima Daiichi Nuclear Power Plant Accident in Japan, Chinese Taipei reviewed its energy policy. On 3 November 2011, President Ma announced a new policy to "Steadily Reduce Nuclear Dependency, Gradually Move Towards a Nuclear-free Homeland, and Create a Low-carbon Green Energy Environment" (BOE, 2012d). The main aspects of the revised nuclear energy strategy are:

- To conduct a comprehensive safety examination of nuclear power plants to ensure nuclear safety
- To steadily reduce nuclear energy dependence by actively reducing electricity demand and peak

load, and by promoting alternative energy sources to ensure stable power supply

- No extension to the lifespan of the three existing nuclear power plants (six units), with the expected first decommissioning to begin in 2018 and all six existing units to be decommissioned by 2025
- The safety of the fourth nuclear power plant (currently in construction) must be ensured prior to its commercial operation
- If the two reactor units of the fourth nuclear power plant are operating securely before 2016, the decommissioning of the oldest nuclear power plant will begin immediately (ahead of the planned 2018 date).

To implement the new energy policy, Chinese Taipei has set a goal for the total installed capacity based on renewable sources to reach 9952 MW by 2025 and 12 502 MW by 2030. This will come from wind power (4200 MW), solar photo-voltaic (3100 MW), hydro (2502 MW), waste (1369 MW), ocean (600 MW), fuel cell (500 MW), and geothermal/bio-gas (231 MW). The installed renewables capacity is also expected to contribute about 10% of the economy's overall power requirement by 2030.

Chinese Taipei's Renewable Energy Development Act (2009) also set up the incentives for private investment in renewable energy which are provided through a feed-in tariff (FIT) mechanism, under which TPC purchases power from renewables generators on contracts involving preferential rates and guaranteed grid connections. The overall aim is to secure the market for electricity generated from renewable energy.

Overall, Chinese Taipei is expected to continue to import almost all of its energy requirements throughout the outlook period due to its lack of indigenous energy sources. To minimize the impact of any oil supply disruptions, Chinese Taipei maintains an oil stockpile of no less than 60 days' supply. The economy has also tried to diversify its energy supply mix by switching from oil to natural gas, coal and renewable energy. In addition, it has started to secure international joint venture agreements to acquire captive supply sources (BOE, 2012e).

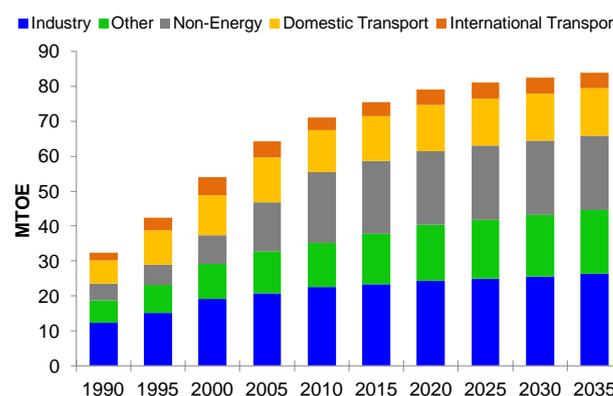
## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Chinese Taipei's final energy demand is expected to grow 0.7% per year over the outlook period. The slowing of demand growth compared to earlier

periods is due to energy conservation efforts in all sectors and the economy's overall industry restructuring. The 'other' sector (which includes commercial, residential, and agricultural use) shows the highest annual growth rate of 1.5%, followed by industry at 0.6%. The economy's final energy intensity is expected to decline by about 52% between 2005 and 2035.

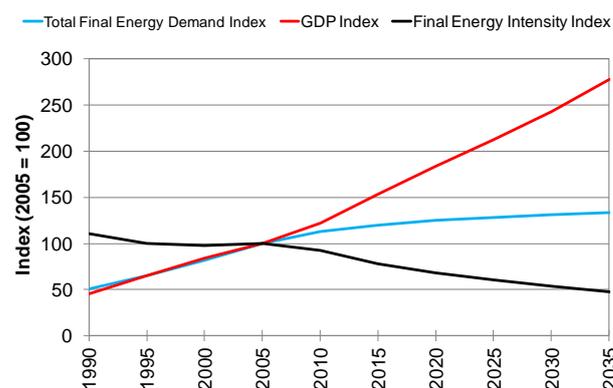
Figure CT2: BAU Final Energy Demand



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure CT3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

### Industry

Energy demand in the industrial sector is projected to grow at an average annual rate of 0.6% over the outlook period; this is lower than the average annual growth rate of 2.5% between 1990 and 2009. This reduction in demand growth is due to structural shift in the industrial sector, from energy-intensive to non-energy-intensive industries, as well as improvements in energy efficiency. The current dominance of the petrochemical industry makes the Chinese Taipei industrial sector highly energy intensive. This energy intensity will reduce, as will the rate of increase in the sector's energy demand, as the electronics and ICT industries are expected to grow more quickly than the petrochemical industry.

The energy mix for the industrial sector over the outlook period shows a slow increase for coal and oil, accompanied by a much more rapid increase in the use of electricity and gas. This energy consumption trend matches the structural change from high-energy-intensive industry to high-value-added electronic or ICT-based industry. Energy intensity in this sector is expected to decline by 1.5% per year over the outlook period.

However, the projection also shows a continued growth in non-energy demand for fossil fuels. Petrochemicals will continue to play a major role in industry and in the economy's overall GDP growth, and Chinese Taipei will remain a larger exporter of petroleum products.

### Transport

Chinese Taipei's transport energy consumption has grown in parallel with its economic development, improvement in living standards, and upgrades in transportation infrastructure. The steep growth of the recent decades is expected to slow over the outlook period. While all domestic transport sub-sectors showed substantial average annual growth of 3.0% between 1990 and 2009, growth is expected to be slower between 2010 and 2035. Projections for the annual growth rate in number of passenger vehicles in use (less than 1.9%), and for motorcycles in use (less than 1.6%) are low, while the number of heavy vehicles (including buses) will grow a little faster (more than 2%).

Total transport energy demand (domestic and international) is expected to grow slowly over the outlook period at an average annual rate of about 0.6%. This is due to improvement in public transportation systems and increases in vehicle energy efficiency. Energy use for domestic transportation has a projected annual growth rate of 0.5%, lower than the international transportation annual growth rate of 0.7%. The growth in international aviation energy demand is based on exports of high-value-added manufacturing products, and the increase in direct air travel between Chinese Taipei and mainland China. To accommodate the predicted growth in air transport, Chinese Taipei has converted Songshan Airport in Taipei city to an international airport, expanded the freight handling capacity at Kaohsiung Airport, and is planning a third terminal at Taoyuan Airport.

Over the outlook period, rail transit systems are expected to gradually replace buses and passenger vehicles for city travel, while high-speed railways are expected to continue to replace passenger vehicles for inter-city travel. As a result, transport oil demand

is expected to grow at an average annual rate of only 0.4% over the outlook period. By contrast, transport electricity consumption is expected to grow at an average annual rate of 5.5%, matching the growth in public transportation systems. However, even in 2035, electricity use in transport will remain small compared to oil use.

### Other

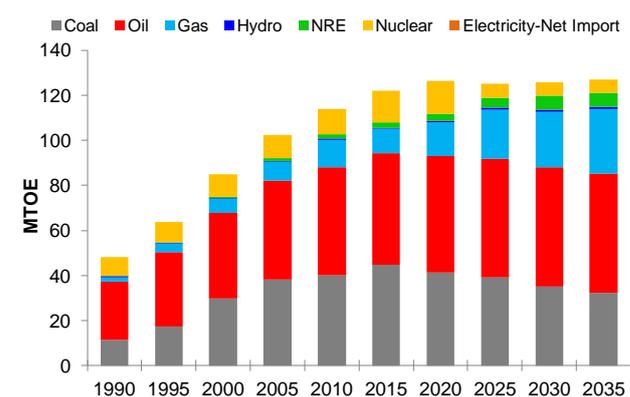
Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is primarily driven by income growth and the improvement in living standards. The 'other' sector energy demand will grow at an average annual rate of 1.5% over the outlook period. Electricity is expected to continue to dominate the energy mix, accounting for 68% in 2035.

However, the annual growth rate for this sector is expected to slow in the long term, based on the adoption of many energy conservation measures, such as increased energy efficiency in appliances and other equipment, replacement and improvement of lighting, as well as incentives for energy conservation. The promotion of zero-energy (and zero-emission) construction will also make a contribution to reducing future energy consumption in the commercial and residential sectors.

### PRIMARY ENERGY SUPPLY

To reduce carbon emissions, Chinese Taipei is gradually reducing coal's share in its primary energy supply (from 38% in 2009 to 25% by 2035).

Figure CT4: BAU Primary Energy Supply



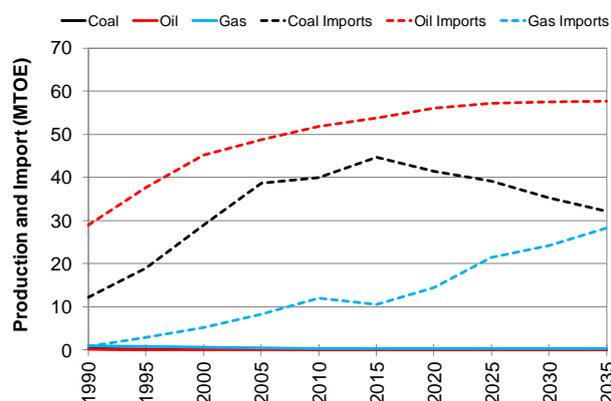
Source: APERC Analysis (2012)

Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Another recent policy initiative requires reduction in dependence on nuclear energy. The reduction in the use of coal and nuclear power will require an increase in the gas share of the primary supply (from 10% in 2009 to 23% by 2035) and more aggressive exploitation of renewable energy sources (from 1% in 2009 to 5% by 2035). The reduction in

coal imports and fast growth in gas imports are shown in Figure CT5.

Figure CT5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

### ELECTRICITY

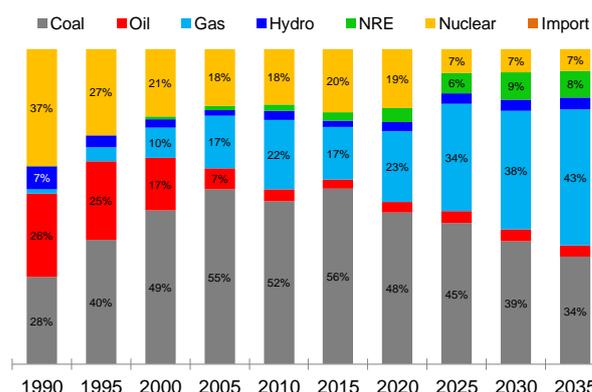
This business-as-usual (BAU) projection takes into account the November 2011 revision of energy policy, which announced the gradual phase-out of existing nuclear power plants.

By 2035, Chinese Taipei’s total installed capacity is expected to reach 73.0 GW. The majority of this will be thermal (76%); this is made up of coal (33% of total generation capacity), natural gas (38%) and oil (5%). Other generation capacity at the end of the outlook period will be from nuclear (4%), NRE (13%), and hydro (7%).

Chinese Taipei’s total electricity generation is projected to increase from 226 TWh in 2009 to 336 TWh in 2035, growing at an average annual rate of 1.2%. Efforts to reduce the economy’s CO<sub>2</sub> emission intensity will mean the share of coal will decrease from 55% in 2009 to 34% in 2035; it will be replaced by increased generation from natural gas and NRE sources. The natural gas share will increase significantly from 20% in 2009 to 43% in 2035.

Nuclear’s share is expected to decrease from 18% in 2009 to only 7% in 2035, as a result of the decision not to extend the lifespan of existing plants. The share of electricity generation supplied by hydro is projected to increase from 2% in 2009 to around 4% in 2035. At the same time, as a result of government policy to promote the development of new and renewable energy sources (mainly wind power), the NRE share will increase from 2% in 2009 to 8% in 2035.

Figure CT6: BAU Electricity Generation Mix



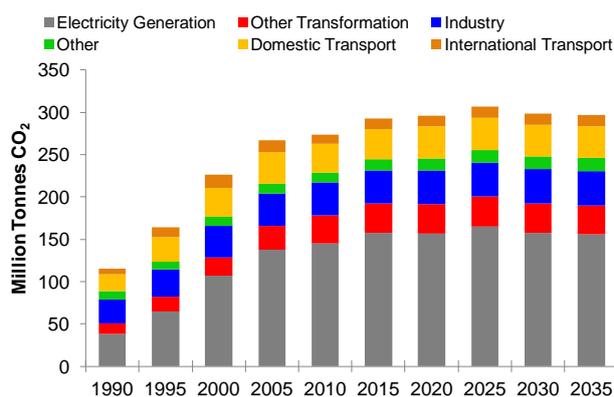
Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

### CO<sub>2</sub> EMISSIONS

Chinese Taipei’s total CO<sub>2</sub> emissions from fuel combustion are projected to reach 297 million tonnes of CO<sub>2</sub> in 2035, which is 15% higher than in 2009 and 158% of the 1990 level. Total CO<sub>2</sub> emissions are expected to peak at 307 million tonnes in 2025. In 2008, Chinese Taipei set a policy goal of a zero increase on 2000 levels (historically 219.4 million tonnes of CO<sub>2</sub> (IEA, 2009, p. III.42))—this projection in 2025 shows an overall increase of 40% on those 2000 levels. This outcome is a consequence of the 2011 change in energy policy to avoid extending the lifespan of existing nuclear power plants and to increase the use of coal- and gas-fired power plants to fill the gap. For Chinese Taipei to meet its own CO<sub>2</sub> emission reduction targets, more development of NRE will be necessary. Current development plans have identified offshore wind turbines and geothermal as potential sources. Another option to reduce CO<sub>2</sub> emissions is adoption of cleaner coal technologies and carbon capture and storage (CCS) in the economy’s coal-fired power plants. Efficient coal technologies are discussed further in Volume 1, Chapter 13.

The electricity generation sector is expected to account for the largest share of CO<sub>2</sub> emissions in 2035 at 52% of total CO<sub>2</sub> emissions (156 million tonnes of CO<sub>2</sub>). The industry sector is the next highest contributor, at 14% (41 million tonnes of CO<sub>2</sub>), followed by the domestic transportation sector at 12% (37 million tonnes of CO<sub>2</sub>).

Figure CT7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table CT1 suggests the growth in Chinese Taipei’s GDP will be offset by a reduction in the energy intensity of GDP (energy efficiency and change in industrial structure) and a small reduction in the CO<sub>2</sub> intensity of energy (fuel switching).

Table CT1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.6%	-1.4%	-0.3%	-0.3%	-0.1%
Change in Energy Intensity of GDP	-0.2%	-2.1%	-2.7%	-2.7%	-2.8%
Change in GDP	5.3%	4.1%	3.6%	3.5%	3.3%
Total Change	5.8%	0.5%	0.5%	0.4%	0.3%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

With limited domestic energy resources, the security of Chinese Taipei’s energy supply is central to its energy policy goals of meeting a growing energy demand while reducing CO<sub>2</sub> emissions. The economy will have to look to low-carbon energy sources, in particular replacing coal with natural gas and renewable energy. Chinese Taipei has already moved to promote renewable energy with the 2009 introduction of the Renewable Energy Development Act, which uses preferential feed-in tariffs and guaranteed grid connections to encourage NRE-based generation.

To decouple energy consumption and GDP growth, the service sector needs to be promoted and expanded and the industry sector needs to move to a less energy-intensive structure. For example, promoting knowledge-based industries in the Green Silicon Island, and other high-value-added and low-energy-intensive scientific industry parks, could be one way to foster a less energy-intensive economy. At the same time, energy efficiency efforts need to be promoted throughout the economy.

The establishment of international stockpiling through regional cooperation could be an important way of stabilizing domestic energy supply, as could the acquisition of equity in international energy resource developments by the government-owned oil company.

### ALTERNATIVE SCENARIOS

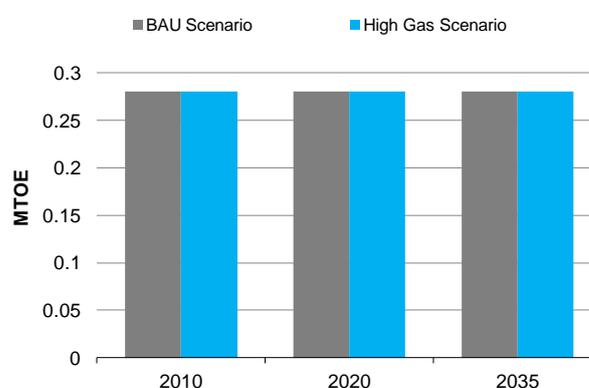
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

However, as Chinese Taipei’s gas resources are very limited, the High Gas Scenario assumes no domestic production increases—as shown in Figure CT8.

Figure CT8: High Gas Scenario – Gas Production

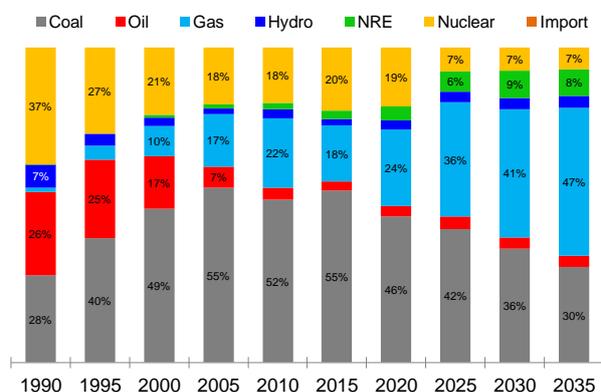


Source: APERC Analysis (2012)

Additional gas consumption in Chinese Taipei in the High Gas Scenario will be a result of increased gas imports, as a result of the improved gas market situation in the APEC region. It will require the expansion of LNG terminals in the economy. Given Chinese Taipei’s aspirations to reduce CO<sub>2</sub> emissions, this High Gas Scenario assumes the additional imported gas would be used to replace coal in electricity generation, as gas generally has less than half the CO<sub>2</sub> emissions of coal when used for electricity generation.

Figure CT9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU case graph shown in Figure CT6. It can be seen that the gas share has increased by 4% by 2035, while the coal share has declined by an equal amount.

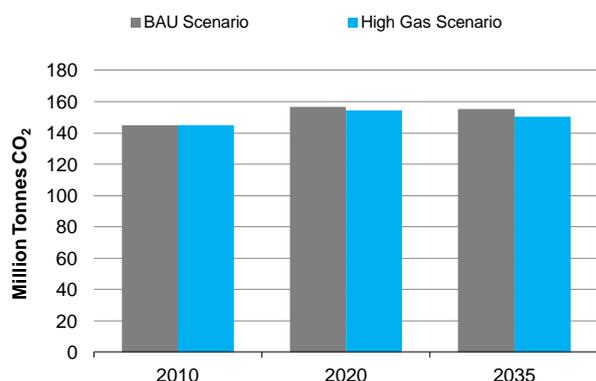
**Figure CT9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

The resulting reduction in CO<sub>2</sub> emissions from electricity generation for Chinese Taipei is shown in Figure CT10. By 2035 there would be a 3.3% reduction compared to BAU scenario emissions.

**Figure CT10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



Source: APERC Analysis (2012)

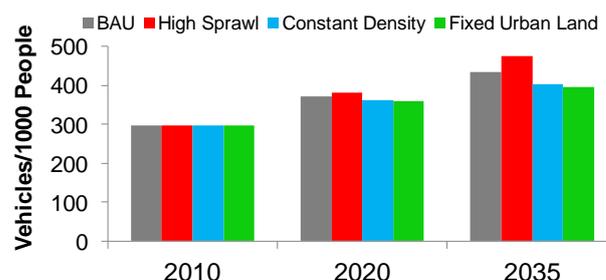
### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CT11 shows the change in vehicle ownership under BAU and the three alternative

urban development scenarios. The difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to BAU in 2035, and about 8% and 9% lower in the Constant Density and Fixed Urban Land scenarios respectively. The model results suggest that better urban planning could significantly reduce the need for people to own vehicles.

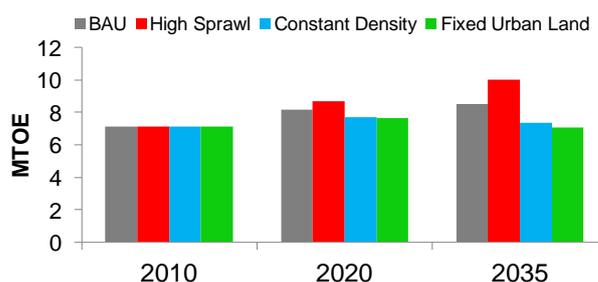
**Figure CT11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure CT12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is even more pronounced than on vehicle ownership, as more compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil consumption would be 18% higher in the High Sprawl scenario compared to BAU in 2035, and about 14% and 17% lower in the Constant Density and Fixed Urban Land scenarios respectively.

**Figure CT12: Urban Development Scenarios – Light Vehicle Oil Consumption**

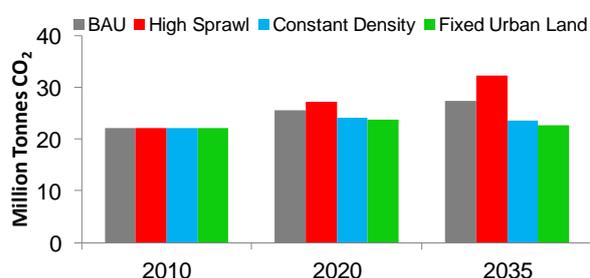


Source: APERC Analysis (2012)

Figure CT13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO<sub>2</sub> emissions would be 18% higher in the High Sprawl scenario compared to the BAU scenario in 2035. They would

be about 14% and 17% lower in the Constant Density and Fixed Urban Land scenarios respectively.

**Figure CT13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



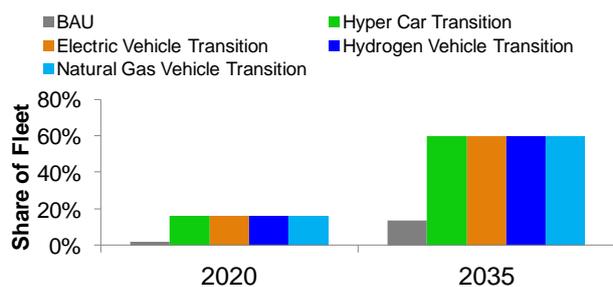
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CT14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 14% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 86% in the BAU scenario.

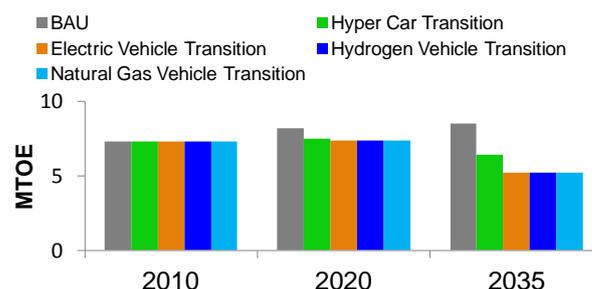
**Figure CT14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure CT15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 39% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 25% by 2035—even though these highly efficient vehicles still use oil.

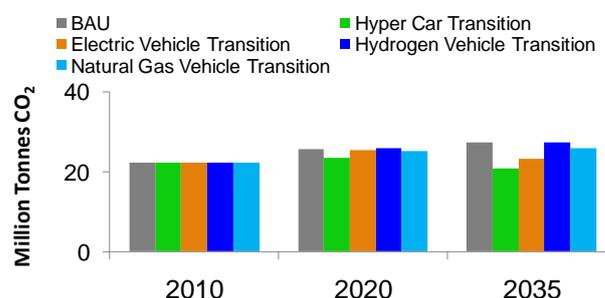
**Figure CT15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure CT16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from its oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure CT16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Chinese Taipei, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emission reductions, with an emissions reduction of 24% compared to BAU in 2035. The Electric Vehicle Transition scenario offers emission reductions of about 15%. The Electric Vehicle Transition scenario in Chinese Taipei because in this economy coal-fired generation would be the marginal source for much of the additional electricity required by the electric vehicles.

Under the Natural Gas Vehicle Transition scenario, 2035 emissions would be reduced by about 5%, reflecting the slightly lower carbon intensity of natural gas and the slightly higher efficiency of natural gas vehicles compared to conventional vehicles. The Hydrogen Vehicles Transition scenario

would have no reduction in emissions. This is mainly due to the way the hydrogen is assumed to be produced—from steam methane reforming of gas, a process that involves significant CO<sub>2</sub> emissions.

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# THAILAND

- Thailand's final energy demand is expected to grow at an average annual rate of 2.6% over the outlook period. This is driven mainly by increased demand in the 'other' sector (which covers residential, commercial and agricultural use) and in the non-energy sector.
- Energy imports are expected to keep growing through to 2035; oil, gas and electricity will all be imported to meet demand.
- Thailand's known domestic oil and gas resources are limited; diversification of supply through the use of renewable and/or alternative energy resources may provide an effective option for improving energy security.

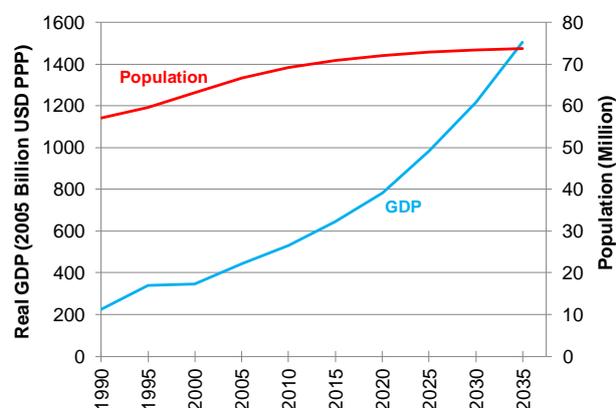
## ECONOMY

Thailand is located in South-East Asia. It is bounded to the west by Myanmar, to the north by Myanmar and Lao People's Democratic Republic (Lao PDR), to the east by Lao PDR and Cambodia, and to the south by Malaysia. It has an area of 513 115 square kilometres and had a population of about 69 million at the end of 2010. The climate is generally hot and humid.

Thailand is the second largest economy in the Association of South East Asian Nations (ASEAN). It is a newly industrialized economy, and heavily export dependent. Its total GDP in 2010 was USD 530 billion (in 2005 USD PPP) or about USD 7675 per person.

Thailand's population is expected to increase at the slow annual average rate of 0.3%, to about 73.8 million by 2035. About half will be living in Bangkok, which is both the capital and the most populous city. Thailand's economy is expected to grow moderately at an annual average growth rate of 4.3% to about USD 1500 billion (in 2005 USD PPP), or about USD 20 390 per person by 2035.

Figure THA1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The World Bank ranks Thailand the fourth easiest place in Asia to do business and seventeenth in the world (The World Bank, 2012). Thailand is a

diversified economy dominated by agriculture and international trade. It is the world's leading exporter of rice and a major exporter of shrimp. Other crops include coconuts, corn, rubber, soybeans, sugarcane and tapioca. The economy is also an automotive and electronics goods exporter.

In 2010 the major energy consumers were the manufacturing and transportation sectors, at 36% and 35% respectively. For the manufacturing sector, most of the demand was for coal (32.6%), followed by renewable energy (27.5%) and petroleum products (10.3%) (DEDE, 2010b, pp. 16–17).

Thailand's transport sector energy consumption is dominated by road transport, which uses 89.4% of transport energy consumption in 2009 (MOT, 2009, p. 14). Thailand's road network is 204 425 kilometres (km) long, of which 30% is classified as national highways. The motorway network is quite small, 226 km at present (NESDB, 2012). The railway network covers a total distance of 4119 km; of this 94% is single-track and 6% (234 km) is double-track (NEDSB, 2012). In 2009, 11 million tonnes of freight and 47 million passengers were transported by the rail network (MOT, 2009, p. 15).

Mass rapid transit (MRT) has become an increasingly significant mode of urban passenger transport, carrying 10% of domestic passengers. In 2011, there were two MRT lines in operation in Bangkok: BTS–Sky Train and MRT–Blue Line, which transport about 600 000 and 190 000 daily passengers respectively (BTS, 2012, p. 31; MRTA, 2012, p. 81). The current total length for these two MRT lines is about 58 km. A bus rapid transit (BRT) system complements the MRT system. The BRT was opened in May 2010 and consists of five bus routes covering 110 km; it can accommodate 50 000 passengers a day (Link Technologies, 2011).

Water transportation plays an important role in Thailand and can be categorized into either inland waterway transportation or coastal transportation. The Mekong River flows through Thailand, allowing international cargo delivery with China, Burma and

Lao PDR. Main domestic inland water routes include the Chaopraya River, Pasak River, Bangpakong River, Mae Klong River and Tha Chin River. Within Bangkok, canals provide an alternative service to the capital's traffic-congested roads.

There are a total of 57 airports in Thailand, of which nine are international airports. In 2010 there were an average 84 450 person-trips per day and 303 ton per day of air cargo delivery (OTP, 2011).

Thailand has formulated an ambitious and comprehensive Transport and Traffic Development Master Plan (2011–2020) with six goals emphasizing sustainability and connectivity. Indicators have been developed to ensure that plans are on track. A total of THB 1862 trillion (USD 60 trillion) has been budgeted for the master plan and will cover all modes of transport.

One key project under this master plan is to develop four routes for high-speed trains that will originate from Bangkok's main terminal: to Chiang Mai in the north, to Nong Khai in the north-east, to Rayong in the east and to Huahin in the south. The plan is to complete the 1915-km high-speed train network by 2032 (NESDB, 2012). A second key project is the metropolitan mass rail transit development project that will consist of 12 routes covering a distance of 495 km and 308 stations. Other measures listed under the Transport and Traffic Development Master Plan are to upgrade the Laem Chabang Port to a world class green port, improve accessibility to public boat transport, and to expand the capacity and upgrade domestic and international airports to be able to handle more customers in a more efficient and sustainable manner (OTP, 2011).

At the end of 2010, Thailand had a total registered gasoline vehicle fleet of 20.5 million units, and diesel fleet of 7.0 million. Motorcycles accounted for 84% of registered gasoline vehicles. Pick-up trucks accounted for 66% of registered diesel vehicles while public buses and trucks accounted for another 11% of the diesel fleet (DLT, 2011). About 90% of all vehicles are domestically produced; the remaining 10% are imported from many economies, mostly from the European Union or United States (DLT, 2011). The consumption of diesel is 2.5 times higher than gasoline due to the significant number of diesel light vehicles in the economy.

In 2010, 98.4% of villages and 86.8% of households in Thailand had access to the electricity network (DEDE, 2010a, p. 5). The use of residential biomass (in the form of charcoal and fuel wood) accounted for 59% of total residential final energy demand in 2010 (DEDE, 2010b, p. xi). It is expected

that this use of biomass for cooking in rural areas will decline as the population increasingly becomes more urbanized.

## **ENERGY RESOURCES AND INFRASTRUCTURE**

Thailand is highly dependent on energy imports, which accounted for 46% of the total primary energy supply in 2009. Imports accounted for 72% of oil demand and 28% of gas demand the same year (IEA, 2011). Oil was mainly imported from the Middle East via tanker, while gas was imported from Myanmar via pipeline.

At end of 2011, the Department of Mineral Fuel reported proven reserves of petroleum both onshore and offshore at 215 million barrels of crude oil, 239 million barrels of condensate, and 284 billion cubic metres (10.06 trillion cubic feet) of natural gas (DMF, 2011, p. 79). Based on 2011 production rates, crude oil reserves will last another four years, condensate reserves another seven years, and natural gas reserves will be depleted in less than 15 years. Although Thailand's coal reserves are large, most of the proven coal reserves are lignite coal of low calorific value. There has been to date no significant assessment of Thailand's unconventional oil and gas resources.

Conservative assumptions suggest that Thailand will need to continue to increase imports of oil and gas from neighboring economies. Thailand has had gas pipeline interconnections with Myanmar since 1999 and Malaysia since 2005; these were constructed as a part of the on-going Trans-ASEAN Gas Pipeline (TAGP) project (ASCOPE, 2010). Within Thailand, the total natural gas network covers 4056 km and natural gas is distributed to power generators, including the Electricity Authority of Thailand (EGAT), independent power producers (IPP) and small power producers (SPP), as well as to 272 industrial users (PTT, 2011a).

Because of the economy's faster than expected growth in demand for natural gas, and the limited scope of its reserves, Thailand is actively seeking new gas resources. It is also seeking to improve security of energy supply by diversifying its power generation fuel mix, through increased use of renewable resources, particularly solar, wind, hydro and biomass.

Liquefied natural gas (LNG) has also been used as a fuel for electricity generation since 2011. The Map Ta Phut LNG Terminal, Thailand's first LNG re-gasification terminal, was inaugurated in Rayong province in September 2011. The terminal has an initial capacity of 5 million tons per annum,

extendable to 10 million tons a year (PTT, 2011b). The anticipated growth in demand for natural gas has led the government to consider building a second LNG terminal, possibly in the south of Thailand to avoid the current freight traffic congestion around Rayong.

Thailand has good potential for generating electricity from renewable energy. Assessments from Thailand's Ministry of Energy estimated that about 57.3 GW of renewable energy capacity may be available, mostly from solar, biomass and wind energy. As of 2010, only 1750 MW of renewable energy capacity had been installed in Thailand, of which 92% was fuelled by biomass (EGAT, 2010, p. 99).

### ENERGY POLICIES

Thailand's energy policy aims for sustainable energy management so the economy has sufficient energy to meet its needs. Currently, it is based on these five strategies:

1. Energy security.
2. Promoting the use of indigenous energy resources including renewable and alternative energy.
3. Monitoring energy prices and ensuring prices are at competitive levels and appropriate for the wider economic and investment situation.
4. Effectively promoting energy conservation and efficiency.
5. Supporting energy development domestically and internationally while simultaneously protecting the environment.

Thailand's energy policy also seeks to build an energy self-sufficient society; achieve a balance between food and energy security; build a knowledge-based society; promote Thailand's role in the international arena; and enhance economic links with other economies in the region to facilitate harmonious cooperation in energy and other sectors.

To improve energy security, Thailand's government has adopted a range of comprehensive measures covering the oil, gas and electricity sectors. The policy development includes comprehensive and careful study of nuclear energy as another option for increasing the stability of the economy's future electricity supply. According to the original Power Development Plan 2010 (PDP 2010), the Electricity Generating Authority of Thailand (EGAT) has estimated that nuclear power could contribute up to 10% of the economy's total electricity generation from 2023 (EGAT, 2010). However, public acceptance of nuclear energy is a major challenge in

Thailand, and an effective communication strategy will be needed to reduce the public's fear of nuclear power and increase recognition of the benefits it would offer to the community. The latest version of the PDP 2010 released in June 2012 reflects this sentiment, and limits the share of nuclear to less than 5% of total generation capacity.

The same revision of PDP 2010 stipulates that Thailand's reserve margin should not be less than 15% of peak power demand and reduces the allowable share for foreign power purchase from neighboring countries from 25% to 15% of total generating capacity.

The Renewable and Alternative Energy Development Plan (2012–2021) sets a framework for Thailand to increase the share of renewable and alternative energy to 25% of total energy consumption by 2021 (DEDE, 2011). The plan states the Thai government will encourage the use of indigenous resources including renewable and alternative energy (particularly for power and heat generation), and supports the use of transport biofuels such as ethanol-blended gasoline (gasohol) and biodiesel. The plan also strongly promotes community-scale alternative energy use, by encouraging the production and use of renewable energy at a local level, through appropriate incentives for farmers. It also rigorously and continuously promotes research and development of all forms of renewable energy.

Thailand has adopted a 20-year Energy Efficiency Development Plan 2011–2030 (EEDP) (EPPO, 2011). This plan sets a target of 25% reduction in the economy's energy intensity by 2030, compared to 2005 levels. In 2011, the EEDP targets were revised to meet the new target declared by APEC Leaders at the APEC Summit 2011. Thailand now aims to achieve a 25% reduction of energy intensity by 2030, compared with 2010 levels (APEREC, 2012). The focus for energy efficiency measures is on transport and industry sectors. If the energy conservation measures can be successfully implemented, energy elasticity (the percentage change in energy consumption to achieve a 1% change in the economy's GDP) will be reduced from an average of 0.98 in the past 20 years to 0.7 in the next 20 years. Implementation of the EEDP will result in cumulative final energy savings of about 289 000 ktoe by 2030 (or an average of 14 500 ktoe per year), and avoided CO<sub>2</sub> emission of 976 million tons (EPPO, 2011). The EEDP employs these strategies:

1. *Mandatory Requirements via Rules, Regulations and Standards.* This includes the enforcement of Minimum Energy Performance Standards

(MEPS), mandatory energy efficiency labelling and enforcement of the Energy Conservation Promotion Act.

2. *Energy Conservation Promotion and Support.* This includes measures for incentives to encourage voluntary energy efficiency labelling, promotion for travelling by mass transit systems, and financial support for Energy Services Companies (ESCO).
3. *Public Awareness Creation and Behavioural Change.* This includes public relations and provision of knowledge about energy conservation to the general public, promoting activities related to the development of a low carbon society and low carbon economy, and the determination of energy prices as a tool to foster public awareness and change energy consumption behaviour.
4. *Promotion of Technology Development and Innovation.* This includes measures to promote research and development to improve energy efficiency and reduce the technological costs, promote demonstrations of technically proven energy efficiency technologies and support for wide commercial deployment of viable technologies.
5. *Human Resources and Institutional Capability Development.* This includes support measures to build professional and institutional capabilities for planning, supervising and implementing energy efficiency conservation measures.

Liquid petroleum gas (LPG) and natural gas vehicle (NGV) fuel prices have been subsidized at below cost levels in Thailand since the 1980s. The price subsidy for LPG and NGV is now being removed, through a gradual increase in price that began in January 2012. The subsidy for transport LPG and NGV will be gone by the end of 2012; the removal of the subsidy for LPG and natural gas for residential, industrial and other sectors will follow more slowly. There will be some government assistance in the residential sector, to offset the increase in the cost of living, before the residential LPG subsidy is completely removed.

Foreign investment in the energy sector is covered by the Foreign Business Act 1999. There is no restriction on foreign investment in businesses involved in energy (oil, gas, electricity) exploration and production. However foreign equity is limited to minority shares of transmission and distribution service businesses. This means foreign companies seeking to operate transmission, trading or distribution services in Thailand require a local joint venture partner. For natural gas transmission and distribution, third parties are able to gain direct access

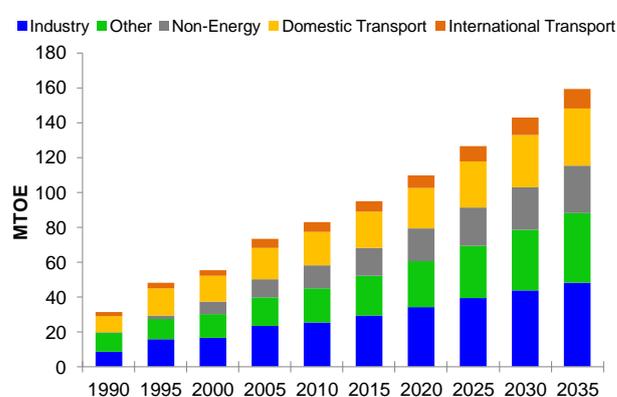
to the network, but there are currently no third party companies doing this (APEC, 2011, p. 392).

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

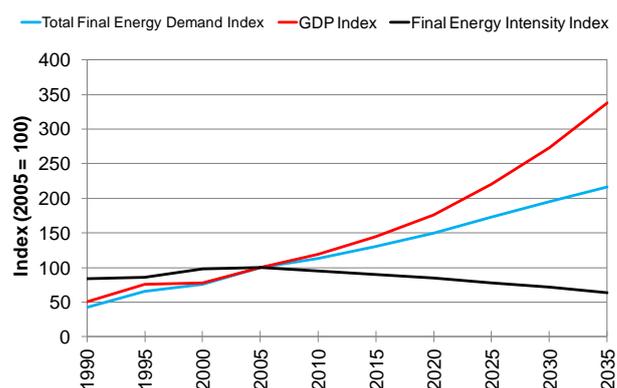
The final energy demand is expected to grow under business-as-usual (BAU) assumptions at an average annual rate of 2.6% over the outlook period (a 92% growth in total). In 2035, industry and non-energy use together will account for 48% of the total final energy demand, while transport will account for 27% and 'other' sector demand for 25%, as shown in Figure THA2. More than half of the final energy demand will be for oil. Natural gas demand will be the most rapidly growing energy source, at an annual average rate of 4.4% per year from 2010 to 2035.

Figure THA2: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011

Figure THA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Thailand's final energy intensity is expected to decrease by over 25% between 2010 and 2030, and over 35% between 2005 and 2035, as shown in Figure THA3. This should meet the economy's own target of 25% energy intensity reduction by 2030, compared to 2010 levels, as set in the Energy Efficiency Development Plan (EEDP).

## Industry

Industry's energy demand is expected to grow by 2.6% per year over the outlook period. This is due to growth in the manufacturing subsector, particularly in food and beverages, chemicals and non-metallic minerals. Coal and electricity are expected to be the largest industrial energy sources. The fastest growing, however, will be oil, which is expected to grow at an average annual rate of 5%, from 2.7 Mtoe in 2009 to 10 Mtoe in 2035.

## Transport

Domestic transport demand is expected to grow by 2.1% per year over the outlook period, due to increasing vehicle numbers (which are still far below saturation level) and the increase in vehicle kilometres travelled. Demand will be moderated by the gradual shift in transport modes in urban centres (to rapid transit systems) and a modest increase in the use of biofuels and alternative vehicles.

The light vehicle fleet in Thailand will be more diverse by 2035. Hybrids and plug-in hybrid vehicles will account for 4% of the fleet, while vehicles running on LPG and CNG will account for 7%.

## Other

Energy demand in the 'other' sector, which includes the residential, commercial and agricultural subsectors, is expected to increase at an annual average of 3.0% over the outlook period, to 40 Mtoe in 2035. A large percentage of 'other' sector demand will be for electricity in the commercial subsector and for oil in the agricultural subsector.

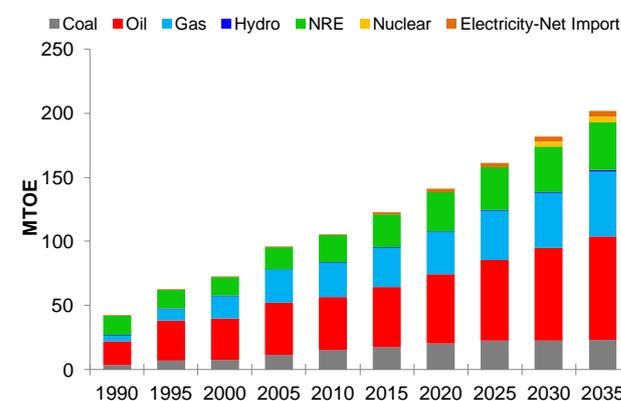
The likely increase in home appliance ownership, and its impact on residential demand, varies between types of home appliance. In 2010, air conditioners were owned by only 15.6% of the households, which is a long way below saturation level. In comparison television and fan ownership levels are much higher: 96% of households own a television and 97% own fans (NSO, 2011). Thailand is promoting energy conservation and efficiency through various measures, including building codes and minimum efficiency performance standards for appliances, and this is expected to moderate electricity demand in this sector.

## PRIMARY ENERGY SUPPLY

Thailand's total primary energy supply is projected to grow at an annual average of 2.6% over the outlook period. Figure THA4 shows oil and gas will dominate the mix, and in 2035 will account for over 65% of total primary energy supply. New renewable energy sources (NRE) are expected to

grow by 77% over the period, and will account for 19% of the 2035 total. In this BAU projection, Thailand will likely introduce nuclear energy into the primary energy fuel mix from 2027 onwards. However, as noted in the 'Energy Policies' section above, there is still much uncertainty about the future of nuclear in Thailand.

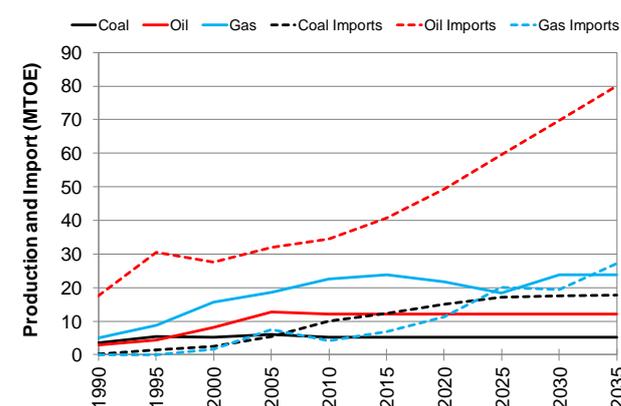
Figure THA4: BAU Primary Energy Supply



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure THA5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Over the outlook period Thailand is expected to remain highly dependent on energy imports, particularly for oil, as seen in Figure THA5. Oil imports are expected to grow at an average annual rate of 3.4%, to 80 Mtoe in 2035. This is to meet the projected demand for oil, especially in the domestic transport and non-energy sectors over the outlook period.

Increasing demand for natural gas, especially for electricity generation, and Thailand's limited gas production will require the economy to increase its gas imports almost four-fold from 7.5 Mtoe in 2009 to 27 Mtoe in 2035. Coal imports are expected to grow at an annual average of 2.3% from 2010 to 2035, mostly serving the industrial sector and electricity generation.

### ELECTRICITY

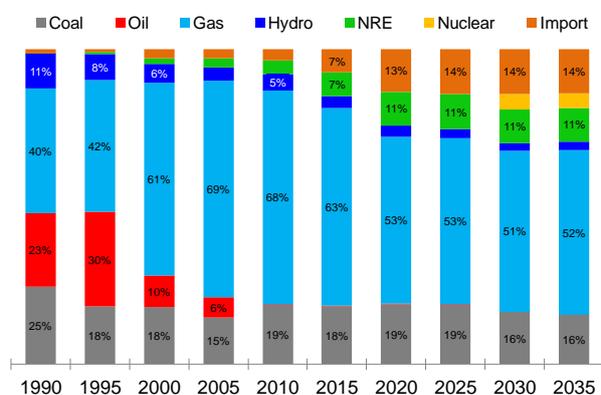
Figure THA6 shows Thailand’s electricity generation fuel mix will remain heavily dependent on natural gas throughout the outlook period. By 2010, oil-fuelled power plants had mostly been removed from use; as a result, the oil share in the total generation mix is almost negligible throughout the outlook period. During the same time, the coal share will be maintained at about 16–19%.

After the Fukushima Nuclear Accident, the Ministry of Energy postponed construction of a proposed nuclear power project and reduced the plant’s final capacity from four 1000 MW units to two: one unit to commence operation in 2026 and the next unit in 2027 (EGAT, 2012). With this latest proposal incorporated, our BAU scenario projects that nuclear energy will contribute about 5% of the electricity generation mix from 2027 onwards. This may still change depending on Cabinet endorsement and public acceptance, as well as the results of feasibility and safety review assessments of Thailand’s nuclear readiness.

The share of electricity generation based on hydro and NRE sources will increase from 9.5% in 2010 to 13.4% in 2035. As a tropical economy with strong agricultural sector, most of Thailand’s NRE will be in the form of biomass, biogas and solar energy.

Thailand has signed a number of Memoranda of Understanding (MOU) with Lao PDR, Myanmar and China to develop power generation projects over the next 20 years to enable Thailand to import electricity from these economies (EGAT, 2010, p. 22). Most are hydroelectric and renewable energy projects. The associated transmission systems are already under construction. As these power purchase projects come online, Thailand’s electricity imports will increase and account for at least 14% of the total electricity generation mix from 2025 onwards.

Figure THA6: BAU Electricity Generation Mix

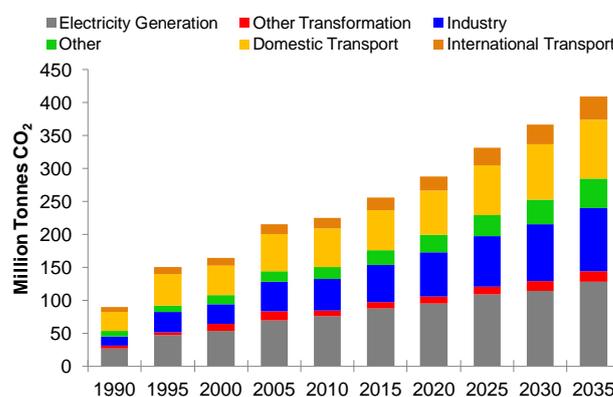


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

### CO<sub>2</sub> EMISSIONS

Thailand’s level of CO<sub>2</sub> emissions is expected to increase throughout the outlook period, across all sectors, as shown in Figure THA7. The average annual rate of increase for the whole economy is 2.4%. Electricity generation, industry and domestic transport will be the main contributors.

Figure THA7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table THA7 shows Thailand’s growth in GDP drives the total change in CO<sub>2</sub> emissions, offset by reductions in CO<sub>2</sub> intensity of energy (fuel switching) and energy intensity of GDP (energy efficiency and industry structure).

Table THA1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	0.4%	-1.0%	-0.4%	-0.4%	-0.2%
Change in Energy Intensity of GDP	0.9%	-1.6%	-1.5%	-1.6%	-1.5%
Change in GDP	4.7%	3.6%	4.1%	4.1%	4.3%
<b>Total Change</b>	<b>6.1%</b>	<b>0.9%</b>	<b>2.1%</b>	<b>2.2%</b>	<b>2.4%</b>

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual assumptions, Thailand’s final energy demand will double within the next 25 years, and with its limited resources, the economy will likely remain a net energy importer to meet its increasing energy demands. The BAU scenario also indicates Thailand’s high dependency on fossil fuels will likely result in the further increase of CO<sub>2</sub> emissions and environmental pollution.

To improve energy security and alleviate the climate change problem, the economy is actively pursuing initiatives in biofuels and natural gas for vehicles, and nuclear and renewable energy in the power sector, as well as diversifying its imported energy resources. The economy already has a 20-year Energy Efficiency Development Plan 2011–2030 in place—this should accelerate energy efficiency and

conservation measures in the economy, with the result of reducing energy intensity by 25% from 2010 to 2030.

### ALTERNATIVE SCENARIOS

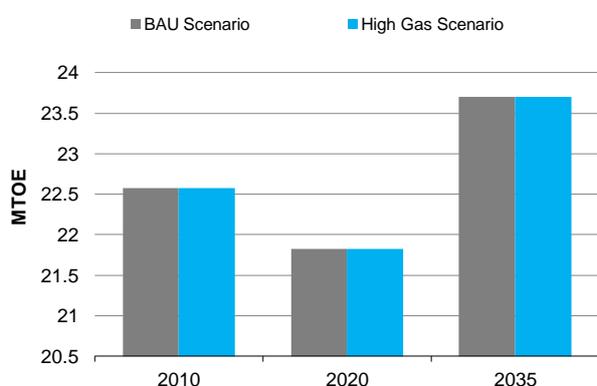
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Due to natural gas resource depletion (DMF, 2010), gas production under the High Gas Scenario for Thailand is likely to be the same as for BAU, as shown in Figure THA8.

Figure THA8: High Gas Scenario – Gas Production



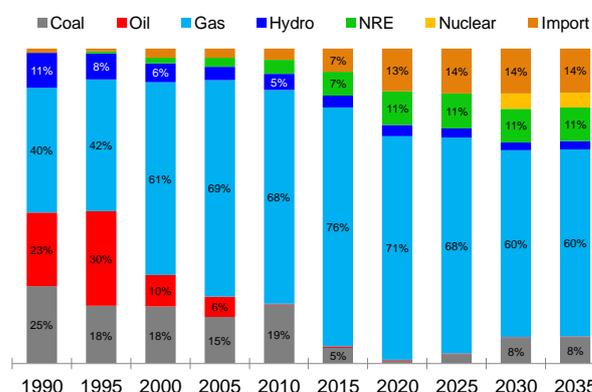
Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. In Thailand, natural gas demand for electricity production is projected to increase over the outlook period; therefore, in a situation of high gas availability, Thailand can be expected to import more gas via pipeline and as LNG to meet the growing demand. The proportion of imported gas will depend on the market situation.

Additional imported gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure THA9 shows the High Gas

Scenario electricity generation mix. This graph may be compared with the BAU scenario shown in Figure THA6. It can be seen that the gas share has increased by 8% by 2035, while the coal share has declined by an equal amount.

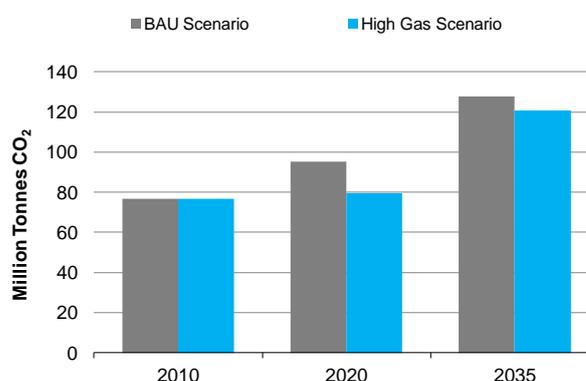
Figure THA9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

Since gas has roughly half the CO<sub>2</sub> emissions per unit of electricity generated than coal, this had the impact of reducing CO<sub>2</sub> emissions in electricity generation by 6% by 2035 as shown in Figure THA10.

Figure THA10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation



Source: APERC Analysis (2012)

The CO<sub>2</sub> emissions reduction in the High Gas Scenario could contribute towards Thailand’s Energy Efficiency Development Plan (EEDP) target to achieve cumulative avoided CO<sub>2</sub> emissions of 976 million tons from 2010 to 2030 (EPPO, 2011, p. 8)

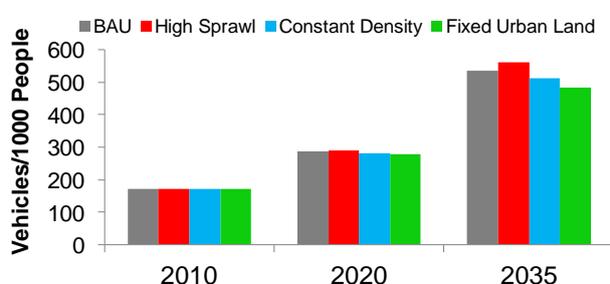
### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative

urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure THA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the High Sprawl scenario and BAU is moderate: vehicle ownership is 5% higher in the High Sprawl scenario. However, there is a significant shift in the Fixed Urban Land scenario, where vehicle ownership is 9% lower than BAU. The impacts of improved urban planning are likely to be more significant in the years after 2035, as vehicle ownership approaches saturation levels typical of wealthy economies.

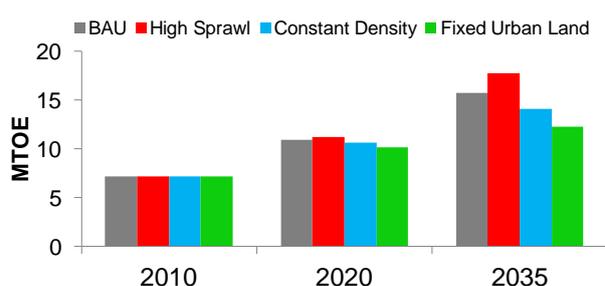
**Figure THA11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure THA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The different urban development scenarios have greater impact on light vehicle oil consumption than they did on vehicle ownership figures. In addition to reducing vehicle ownership, denser urban development also reduces the length of vehicle trips. Light vehicle oil consumption in the High Sprawl scenario is 13% higher than BAU, while in the Constant Density and Fixed Urban Land scenarios, it is 10% and 22% lower, respectively.

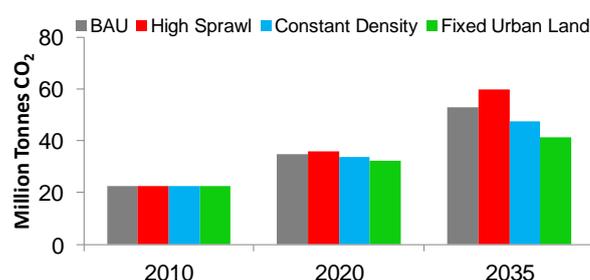
**Figure THA12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure THA13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO<sub>2</sub> emissions would be 13% higher in the High Sprawl scenario compared to BAU in 2035, and about 10% and 22% lower in the Constant Density and Fixed Urban Land scenarios, respectively.

**Figure THA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



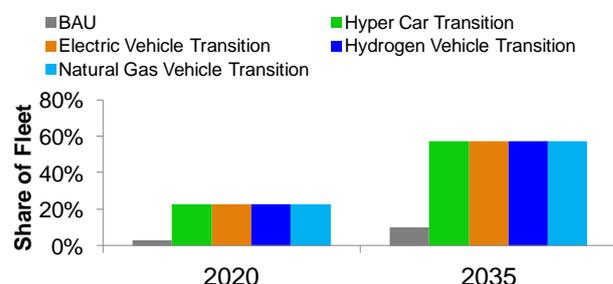
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure THA14 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios.

**Figure THA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**

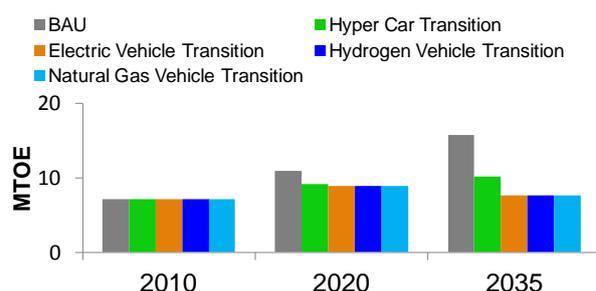


Source: APERC Analysis (2012)

By 2035 the share of the alternative vehicles in the fleet reaches around 57% compared to about 9% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 43%, compared to about 91% in the BAU scenario.

Figure THA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 51% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 35% by 2035, even though these highly efficient vehicles still use oil.

**Figure THA15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

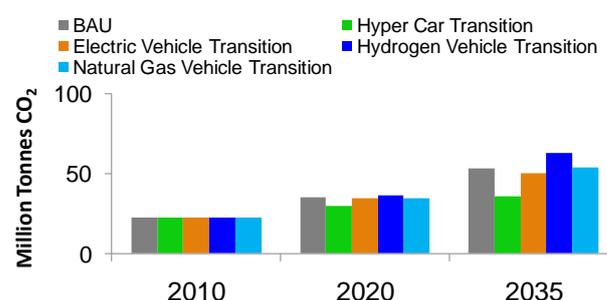
Figure THA16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Thailand, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emission reduction, with an emission reduction of 32% compared to BAU in 2035. This is because of the higher fuel efficiency in hyper cars reduces the oil consumption per kilometre travelled. The Electric Vehicles Transition scenario would be second, offering a reduction of 6% compared to BAU in 2035. While electric vehicles and the power plants that supply them use energy more efficiently than conventional vehicles, this scenario assumes they still rely on fossil-fuel generated electricity, which in Thailand is mainly from natural gas.

In contrast, the Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios would actually increase emissions level, by 2% and 18% respectively, compared to BAU in 2035. Thailand has a large proportion of diesel and LPG light vehicles,

which are more efficient than light vehicles using regular petrol or natural gas as fuel. This means there is actually a drop in efficiency when switching to natural gas vehicles, which causes a small increase in emissions for the Natural Gas Vehicle Transition scenario. The large increase in emissions for the Hydrogen Vehicle Transition scenario reflects the conversion losses in producing hydrogen from gas which involves significant CO<sub>2</sub> emissions. The results would be more favourable if hydrogen could be produced from a renewable or low carbon energy source.

**Figure THA16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# UNITED STATES

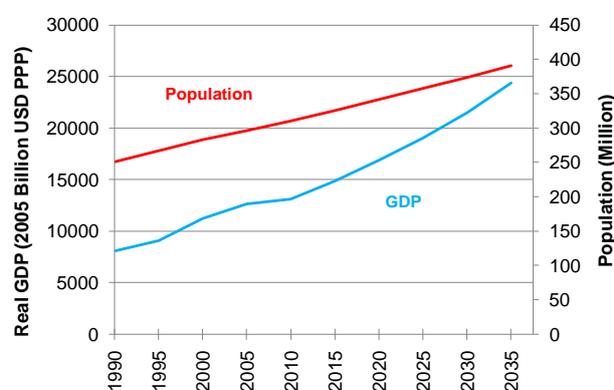
- *Economic recovery and population growth combined with aggressive energy efficiency policies will see the US energy demand grow slowly over the 2010–2035 outlook period.*
- *The US has uncovered vast shale oil and gas reserves which will see domestic production dramatically reverse its long standing decline and accelerate US energy security and economic growth.*
- *Coal use will decline quickly in the electricity sector. Total annual CO<sub>2</sub> emissions from fuel combustion will decline to around 5050 million tonnes in 2035 or 13% lower than in 2005. However, emissions per capita will still be higher than most other wealthy economies and above the level required worldwide to avoid damaging climate change.*

## ECONOMY

The United States (US) is the world's largest economy. In land area, it is geographically diverse and resource rich.

The US population was about 310 million in 2010 and continues to increase steadily as a result of positive immigration, a stable replacement birth rate (about 2.05 births per woman) and a positive ratio of births to deaths (CIA, 2011). The population is expected to grow to around 391 million over the outlook period. About 82% of the population is urban—this is projected to increase in share to 88% by 2035 (UN, 2011).

**Figure US1: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

Economic growth in real GDP will be moderate, with a growth rate averaging 2.5% per year between 2010 and 2035. By 2035, total GDP is expected to reach USD 24.3 trillion in real 2005 dollars

The average per capita income in real 2005 dollars was USD 42 200 in 2010, which using purchasing power parity (PPP) per capita places the US comfortably in the top 10 wealthy economies in the world (IMF, 2011). However, the distribution of wealth in the US is among the most unequal for a mature and developed economy (CIA, 2011). The percentage of people below the defined poverty line

was approximately 15% in 2010, the highest level since 1993 (US Census Bureau, 2011b).

Owing to its geographical size the US has a diverse climate and landscape. The vast majority of the US has a moderate climate which supports its large tracts of arable and fertile land. However, the southwestern states tend to be very dry, and their agriculture depends on artificial irrigation. Almost all areas typically experience heat waves during summer; the northern regions experience severe cold and snow storms during winter. Summer cooling and winter heating of buildings are almost universal. The western US states are geologically prone to earthquakes; the states in the mid-west and in the Gulf of Mexico are also prone to severe weather events such as tornados and hurricanes.

The US enjoys one of the highest standards of living in the world. The economy relies on domestic consumption, which accounted for 70% of total GDP during the decade up to 2010 (Hubbard and Navarro, 2010). The US economy is highly service based, and supported by a productive and educated workforce. The US has a net trade deficit which equated to about 3.4% of GDP in 2010 (US Census Bureau, 2011c). Other key sectors include agriculture, manufacturing and mining.

The industry sector is one of the major energy consumers in the US economy. This sector is made up of energy intensive industries, such as those that produce aluminium, chemicals, paper and steel. The US has a growing high-tech industry which is less energy intensive than the older 'smokestack' industries. A shift toward less energy intensive industries has also been driven by growing global competition for low-tech industrial production. This has led to the gradual shift to a service based economy.

US cities were developed during the advent of cheap energy and an ample supply of land. Consequently, US cities have high levels of urban sprawl which has led to high per capita vehicle

ownership. The US also has the world's largest interconnected highway system and a comprehensive network of urban and intercity motorways. The combination of high vehicle ownership, an extensive highway network and low attention to energy efficiency has led to especially high transport energy use per capita. The economy's dependence on automobile mobility is unlikely to change by 2035.

Automobiles and air transport are the dominant means of intercity passenger travel. US public transport is typically of fair to poor quality relative to other industrialized economies, and its market share is relatively small outside of a few cities with compact central business districts (such as New York). The public transport system is heavily subsidized with ticket revenue comprising only about 38% of operational costs in 2010. However, since 1995, public transport has seen sustained growth with total transit trips increasing over 30% between 1995 and 2010. This growth was more than twice the rate of population growth over the same time (APTA, 2012).

The US has a diverse freight transport industry which includes many kinds of highway carriers, ocean and inland waterway shipping, and domestic and international air freight. Most interesting, from an energy perspective, is the US rail freight system. It is largely unsubsidized and considered to be one of the world's most productive and efficient rail freight systems (The Economist, 2010). In terms of ton-miles, rail freight accounted for about 37% of total freight volumes in 2009 (RITA | BTS, 2012).

The US has a particular endearment for sport utility vehicles and pick-up trucks which represented a 43% share of the total light vehicle fleet in 2011 (USDOE, 2012). The rapid rise in oil prices since the early 2000s combined with the onset of the financial crisis in 2008 has caused a severe downturn for US automobile companies. From 1998 to 2010, the light vehicle market share of the three major US automobile companies, General Motors, Ford and Chrysler has declined from 70% to less than 50% (Motor Intelligence, 2011). The US does not import used automobiles, but exports used vehicles, largely to its southern neighbour, Mexico.

## ENERGY RESOURCES AND INFRASTRUCTURE

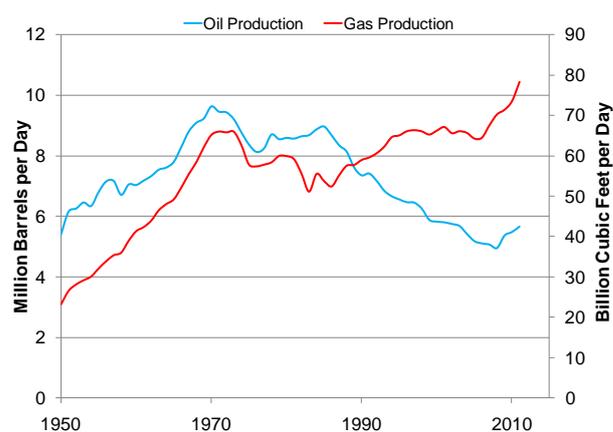
The US energy scene has changed remarkably. The economy historically ranked as APEC's second largest oil and gas producer (after Russia). However, until recently, it was widely viewed as being on a long-term path to growing oil and gas import dependency as a result of declining oil production and stagnant gas production. This outlook has

changed dramatically as a result of the exploitation of new technology for producing unconventional gas and oil, most notably 'shale gas' and 'shale bearing oil'. These technologies are discussed in Volume 1. The US has been the world leader in the development and exploitation of these technologies and their impact on the US oil and gas supply outlook has been significant.

The new technologies have resulted in an increasing production of natural gas and a precipitous drop in gas prices since 2008. The economy is believed to have huge unconventional gas resources with recoverable reserves from shale basins across the US estimated at 482 trillion cubic feet (13.6 trillion cubic metres) (EIA, 2012a). It is likely the US, historically a modest gas importer, will become a modest gas exporter in the 2010–2035 outlook period. The access to plentiful gas supplies and at relatively low prices will unlock further demand in transport, for new electricity generation and directly in industry applications.

Oil production has similarly reversed its decline, aided by rising world oil prices. In addition to shale bearing oil, the US is likely to have significant resources of deep water offshore oil, which can also be exploited using new technology. Although this technology suffered a setback with the Deepwater Horizon oil spill in the Gulf of Mexico in 2010 (see 'Energy Policies' below), the long-term prospects remain solid. The US is a net oil importer—the economy imported a peak of 60% of its demand in 2006 but this dropped steadily to less than 50% of its demand in 2010.

**Figure US2: Domestic Oil and Natural Gas Production**



Source: Adapted from EIA, 2012b and 2012c

The US is the world's second largest coal producer (after China). US coal reserves are immense, equating to more than one-quarter of the global coal reserves in 2010 and over 200 years of supply at current rates of production (BP, 2011).

Although fossil fuels still dominate the US primary energy mix, new and renewable energy (NRE) resources are growing fast. US biofuel is supplied almost exclusively by corn-ethanol distillers, but cellulosic feedstocks are a promising technology for the future. The economy's capacity to sustainably supply biomass feedstocks for energy use is estimated to exceed 1 billion tonnes per year, which might displace 30% of its current petroleum consumption (USDOE, 2011). Since 2000, following the push to reduce US foreign oil dependency, US biofuel production has risen almost 10-fold to 13.3 billion US gallons (320 million barrels) in 2010 (EIA, 2011). The sustained growth in biofuel production was supported by generous federal subsidies. Currently, in the face of high oil prices and rising budget deficits the federal government is debating whether to continue biofuel subsidies at current levels. The future growth in biofuel production is likely to slow as a result of supply constraints on corn feedstock and of the high cost of using more abundant cellulosic feedstocks.

Wind and solar energy, like biofuels, have a large development potential and have experienced rapid growth in recent years. In 2010 alone, the total wind energy capacity installed was 5116 MW, and from 2007 to 2010 wind installations accounted for over 35% of all new US electricity generating capacity (AWEA, 2010). Solar photovoltaic and thermal systems are also growing rapidly. In 2010, solar installations by capacity reached 956 MW or almost double that in 2009. However, subsidies and state regulations are key mechanisms that have supported NRE and its future growth is dependent on this support continuing in the short term.

The US geothermal capacity is less than 4 GW, with planned capacity additions totalling a further 5 GW (NREL, 2011). Geothermal energy provides largely baseload power using the energy potential of high temperature fluids, located in shallow and extractable geological formations underground. The limited number of drilling locations with high temperature underground resources at shallow depths has restricted new generation capacity. The future of geothermal will largely be limited outside of the planned capacity additions. However there is a lot of potential in the commercialization of technology for deep enhanced geothermal extraction, where the US has vast untapped resources.

The US has the world's largest nuclear generating capacity with 104 nuclear plants, providing nearly 20% of the economy's electricity generation. The last new reactor to join the fleet was brought online in 1996. The high initial cost of nuclear plants, regulatory uncertainties, low demand growth, safety

concerns, and the unresolved issue of waste disposal are the major obstacles to adding new reactors. Several new nuclear reactors (largely within existing nuclear facilities) are awaiting the approval of the NRC (Nuclear Regulatory Commission) with four recently approved for construction. The US federal government provides generous financial incentives including tax credits, loan guarantees, insurance protection, waste disposal and funding support for advanced reactor technology (WNA, 2012). Growth in nuclear energy is likely to be slow, with competition from low-cost natural gas posing a major threat.

## ENERGY POLICIES

The US has a provisional target to reduce total GHG (greenhouse gas) emissions by about 17% below a 2005 baseline, by 2020 (USDOE, 2009). The US did not ratify the Kyoto Protocol, but many states have adopted legislation intended to limit GHG emissions. Twenty-two states, collectively home to nearly half the US population, have adopted GHG emission reduction targets, although the stringency of these varies considerably (Pew Centre, 2012). It is unlikely the US will agree to binding targets or will adopt a carbon tax in the immediate future, due to strong opposition to such measures.

Many states have adopted policies to increase the share of renewable energy in the electricity generation mix. Twenty-eight states have adopted a mandatory renewable portfolio standard (RPS). Such policies require a certain share of retail electricity sales to be provided by renewable generation by a specified year. The share and the year vary state by state, as do other provisions, such as the eligible technologies and the trading of renewable energy credits. For example, the Pennsylvania RPS requires 8% 'Tier 1' renewables by 2020 and defines methane from coalmines as an eligible resource, while the California RPS targets a 33% share of renewables by 2020 and has a more common definition of renewable energy (NCSU, 2007). In California the RPS is proving effective at stimulating NRE development. Since 2003, 2871 MW of eligible NRE capacity has been installed under the RPS mandate, and several compliance targets on the path to the 2020 target have been met. A further 2500 MW of NRE is expected to be commissioned by the end of 2012 (CPUC, 2012).

There are three policies likely to have a substantial impact on both US energy consumption and emissions. These are the new emission standards on pollutants and toxins issued by the Environmental Protection Agency (EPA), the revised corporate average fuel economy (CAFE) standards and the

EPA's proposal to introduce a restriction on carbon emissions in the power sector.

Firstly, the new EPA emission standards on mercury and toxic pollutants will be incrementally applied from 2012. The strict emission standards will be fully enforced by 2015. This will have a major impact on reducing toxic emissions from coal, primarily in the electricity sector (EPA, 2012b). The new standards will require expensive technological retrofits to existing facilities, and will affect almost half the coal generating capacity. Most of the affected coal facilities are over 40 years old and the new standards are likely to result in extensive capacity retirements which may exceed 50 GW.

Secondly, the revised CAFE standards are expected to be finalised in mid-2012. These require new passenger cars and trucks to meet higher fuel economy standards in the years ahead. Specifically, new passenger vehicles and light trucks are required to achieve an annualized fuel economy improvement of 5% and 3.5% per year, respectively, until 2025. For passenger vehicles, the new standard aims to increase the average new vehicle fuel economy from 27.5 miles per gallon in 2010 to 54.5 miles per gallon (23.2 kilometres per litre) by 2025, and to the 'maximum feasible standard' after that (NHTSA, 2011). The new standards have several loopholes which may inhibit their effectiveness. The chief concern is the use of a size weighted average fuel economy, where larger vehicles have lower fuel efficiency targets. This policy was included to eliminate penalties which favour the sales of small vehicles over large vehicles. However, sales of larger vehicles may increase in market share and reduce real fuel efficiency improvements. A published study suggests average vehicle sizes, particularly for light trucks, may increase between 2% and 32% under the new standards. This would result in a net reduction in the average fuel economy of between 1 and 4 miles per gallon (between 0.4 and 1.7 kilometres per litre) (Whitefoot and Skerlos, 2011). Other uncertainties which may reduce the standards' effectiveness include low fees for non-compliance, overstated fuel economy ratings and low targets for heavy trucks. These negative effects are expected to be limited and real efficiency improvements are likely to accelerate under these rules, but perhaps at a less than anticipated rate.

Finally, the EPA is proposing to limit CO<sub>2</sub> emissions in the power sector. The proposed standard restricts CO<sub>2</sub> emissions to a limit of 454 kilograms (1000 lb) for every megawatt-hour of electricity produced. These proposed restrictions only apply to new generating units and exclude existing units in operation or under construction. The

regulation is aimed at limiting climate change by enforcing the use of modern and more efficient fossil fuel generation technologies (EPA, 2012a). The carbon restriction will essentially require new coal plants to operate using the latest high efficiency technology or to employ carbon sequestration. However, at the time of writing, the proposed standards are still under appeal thus adding uncertainty to whether the restrictions will become law.

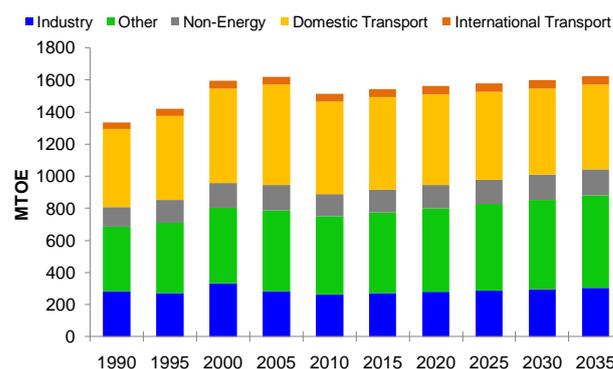
Oil exploration suffered a major setback in the wake of the deep water BP oil spill in the Gulf of Mexico in July 2010. A moratorium on new deep water exploration was initially enforced, but lifted in October 2010 with improved safety regulations on future deep water drilling operations. The US has an extensive, efficient, diverse and long standing oil and gas exploration industry. The oil and gas industry is entirely privately owned and foreign investment is generally welcomed. Tax breaks for major exploration companies are under political scrutiny: however, the industry is supported by robust growth in unconventional oil and gas exploration.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at only 0.3% per year over the outlook period. The largest component of demand growth will be from the 'other' sector (residential, commercial, and agriculture). Growth in transport will remain flat.

Figure US3: BAU Final Energy Demand

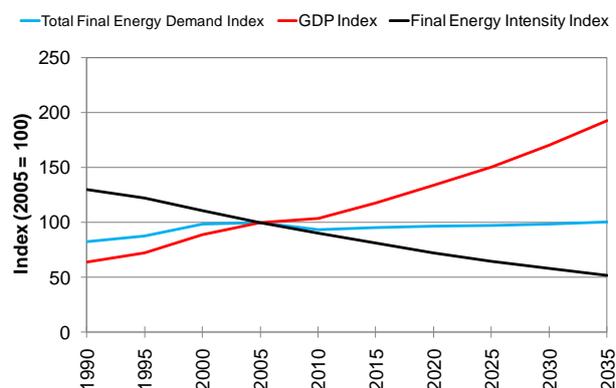


Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 42% between 2005 and 2035.

**Figure US4: BAU Final Energy Intensity**



Source: APERC Analysis (2012)

### Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.6% until 2035. Productivity per worker will continue to rise in manufacturing due to increasing global competition from developing economies. The same competition is also driving improvements in energy efficiency. As the US shifts towards an increasingly service based economy, manufacturing growth will be flat with light industry growth robust. Growth in energy intensive raw product industries such as aluminium, paper, chemicals, cement and steel will be robust with the supply of cheap energy from shale gas. Energy consumption in the industry sector will increase from about 260 Mtoe in 2010 to 300 Mtoe by 2035.

### Transport

Over the outlook period, transport energy demand is projected to decline slightly, with an annual decline rate of 0.3%. Energy demand in the international aviation and shipping sector will rise modestly, but the reduction in the domestic transport sector will be more substantial.

For domestic transport, vehicle ownership in the US has reached saturation level. The US automobile fleet will continue to increase slowly in line with population growth, but improved vehicle fuel efficiency combined with consumer response to increasing oil prices will offset the effect of a growing population. Additionally, alternative vehicles will have a modest entry into the market by 2035, with more funding going into R&D and with the support of tax credits and subsidies. With rising oil prices the share of more efficient conventional vehicles such as diesel and CNG (compressed natural gas) vehicles will also

modestly increase. Conventional hybrid vehicles (gasoline and diesel) will make up about 13% of the fleet by 2035, with plug-in hybrids accounting for around 10% and hydrogen fuel cell and fully electric vehicles less than 3%.

### Other

Energy demand in the ‘other’ sector, which includes residential, commercial and agricultural demand, is expected to grow the most of all sectors at 0.7% per year over the outlook period. Electricity is expected to remain the main fuel source in this sector, accounting for about 50% of its energy consumption throughout the outlook period.

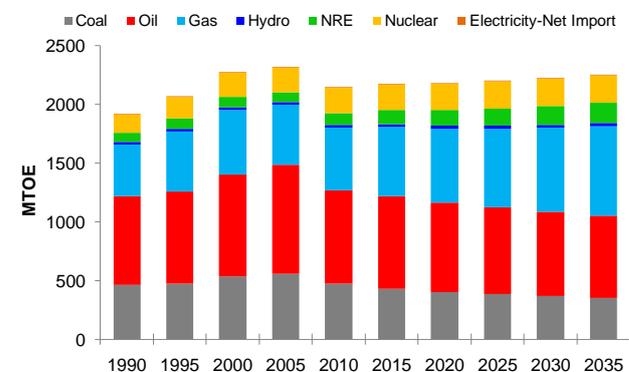
The US median residential floor area increased 36% on average between 1980 and 2010 (US Census Bureau, 2011a). Following the financial crisis in 2008, house sizes have stabilized. With rising urbanization and rising energy prices, floor spaces are expected to remain stable in the outlook period with the demand for small inner city homes outpacing the demand for outer city homes.

The US has a regulatory framework to provide rebates, incentives and R&D in energy efficiency measures. Energy efficiency is a key innovation tool for economic growth. The slight growth in ‘other’ sector energy demand will be driven by a robust growth in agriculture and by the growth in population. This will offset any energy efficiency improvements.

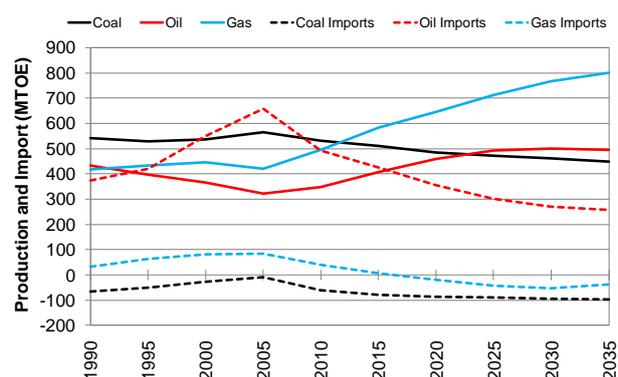
### PRIMARY ENERGY SUPPLY

The US primary energy supply in the 2010–2035 period is projected to grow at an annual rate of about 0.2%. The economy will undergo a structural change in primary energy supply fuels, with the share of low carbon fuels increasing rapidly.

**Figure US5: BAU Primary Energy Supply**



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

**Figure US6: BAU Energy Production and Net Imports**

Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The Obama administration announced a target to reduce US foreign oil imports by one-third by 2025 (Reuters, 2011). In fact, US oil imports are likely to decline over the outlook period to 2035. Under a BAU scenario, a 33% reduction in oil imports from 2010 levels is likely to be achieved at or before the target of 2025. Additionally, the US has aggressively increased its production of biofuel as a direct substitute for oil. The future growth of biofuel is largely dependent on cellulosic feedstock (2nd generation) technology. Cellulosic biofuel is still in the infancy stages—high costs and the need for further advances in technology inhibit its commercialization. Therefore the growth of biofuels is likely to be slow in the medium term until the technology and economics are firmly established.

The acute shortage of domestic natural gas from as early as 1990 led to growing LNG (liquefied natural gas) imports. This equation has changed with unconventional gas production and, assuming government approval, the US is likely to become a modest LNG exporter perhaps as soon as 2017. This is based on an assumption the federal government will not unduly withhold granted export exemptions. At the same time, reduced coal use in electricity generation combined with a strong global coal demand will increase US coal exports. Net domestic coal production will gradually decline.

The medium term outlook for reducing the economy's import dependency is relatively certain, but the long term outlook is not. Unconventional oil and gas technologies are still developing and therefore the ultimate potential of these resources is uncertain. Since the start of commercial shale gas production, technically recoverable shale gas reserve estimates have steadily increased, but recent estimates for 2012 have reduced shale gas reserve estimates 42% from those made in 2011. Technically recoverable shale gas estimates for 2012 stand at

482 trillion cubic feet (or 13.6 trillion cubic metres) but these estimates are uncertain (EIA, 2012a). A further reduction in both the developable unconventional oil and gas resources may see energy dependency reverse its trend in the long term outlook.

## ELECTRICITY

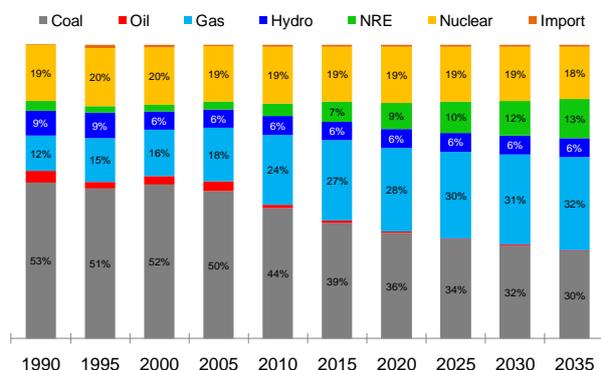
The US electricity sector will also undergo significant changes in the outlook period. In 2011, the EPA (Environmental Protection Agency) issued strict new emission standards for mercury and toxic pollutants (EPA, 2011). The new standards require half of the existing coal generation facilities to either undergo expensive retrofits or to shut down to comply. At the same time, the proposed limits on CO<sub>2</sub> emissions in the power sector add much uncertainty to the economics and regulatory environment of new coal generation. Accompanying the raft of regulatory restrictions, low natural gas prices and subdued electricity demand are putting more pressure on the economics of coal generation. The reduction of capacity by retirements and the diminishing use of coal will result in coal's share of electricity generation dropping from 45% in 2010 to 30% by 2035.

Low cost shale gas and supply security will underpin the growth of high efficiency CCGT (combined-cycle gas turbine) capacity. The share of natural gas generation will increase from 24% in 2010 to 32% by 2035. Additionally, the contribution of NRE will increase over three-fold from about 4% to 13%. Growth in NRE will be led by wind and solar generation, due to reducing installation costs, the attractiveness of the resources and continuing regulatory state and federal incentives. The vast majority of the nuclear energy generating facilities are assumed to extend their operating life to 60 years. Slow capacity growth occurs by up-rating investments in existing reactor facilities. New nuclear reactor additions are unlikely as a result of weak demand growth and low-cost natural gas undermining the capital intensive economics of new nuclear facilities.

The long term stability of natural gas prices and the eventual size of proved shale gas reserve estimates are uncertain. Higher natural gas prices could limit natural gas generation uptake. This in turn is likely to reduce the retirements in coal generation facilities and to improve the growth in NRE and nuclear generation. Additionally, the introduction of a carbon cap, trade or tax is a highly uncertain policy measure with major implications. A moderate carbon pricing policy will significantly improve the growth of NRE and nuclear generation, chiefly at the expense

of coal growth and modestly at the expense of natural gas growth.

Figure US7: BAU Electricity Generation Mix

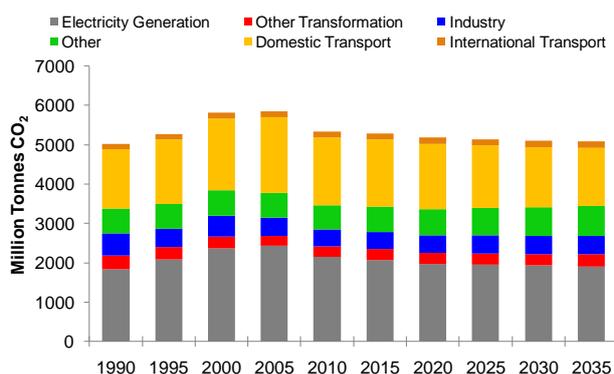


Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

### CO<sub>2</sub> EMISSIONS

Total CO<sub>2</sub> emissions from fuel combustion reached a peak of about 5850 million tonnes in 2005. It is projected total CO<sub>2</sub> emissions will steadily decrease to around 5100 million tonnes or some 13% lower than the historical peak. Electricity generation emissions will lead the decline with reducing coal generation and growing contributions from natural gas and NRE. However, increasing energy demand from both the industry and ‘other’ sectors will limit the rate at which emissions reduce. Transport sector emissions will remain the same due to the stable use of oil.

Figure US8: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table US1 below suggests the growth in GDP will be more than offset by both a reduction in the CO<sub>2</sub> intensity of energy (fuel switching) and a reduction in the energy intensity of GDP (energy efficiency).

Table US1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	-0.3%	-0.4%	-0.4%	-0.4%	-0.4%
Change in Energy Intensity of GDP	-1.7%	-2.2%	-2.2%	-2.2%	-2.3%
Change in GDP	3.1%	0.7%	2.2%	2.2%	2.5%
Total Change	1.0%	-1.8%	-0.6%	-0.5%	-0.2%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, the US energy outlook is reasonably positive. Energy security and per capita GDP will increase, while CO<sub>2</sub> emissions will stabilize at a level 13% lower than in 2005. US per capita CO<sub>2</sub> emissions from fossil fuels remain stubbornly high at about 17.2 metric tonnes per capita in 2010. By 2035, per capita CO<sub>2</sub> emissions from fossil fuels are expected to decline to about 13.0 metric tonnes per capita. However, the US still has significant room to reduce emissions which far exceed the global average needed to prevent damaging climate change. Owing to its status as the world’s largest economy and the world’s third largest by population, the US is a vital player in any global emissions reduction agreement. The introduction of a carbon tax will have a substantial impact on US CO<sub>2</sub> emissions. In particular, electricity generation is likely to respond to carbon pricing by reducing coal use.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

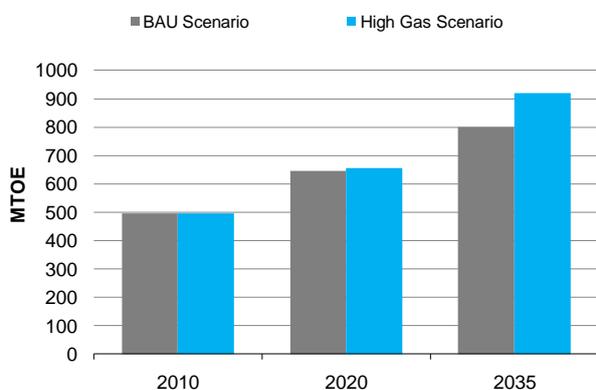
#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario production for the US assumed the production increase shown in Figure US9, which equals 15% by 2035. The US has vast reserves of shale gas which require significant investment in both production and transport infrastructure. The High Gas Scenario assumption primarily removes the restrictions on exports to non free trade economies (which currently require government approval). In turn, this enables greater investment into shale gas production for LNG exports from both the Gulf of Mexico and the West

Coast basins to international markets. The High Gas Scenario also assumed the vast conventional North Slope gas reserves in Alaska are incrementally developed with the project economics supported by improved access to key Asian markets such as Japan and China.

Figure US9: High Gas Scenario – Gas Production

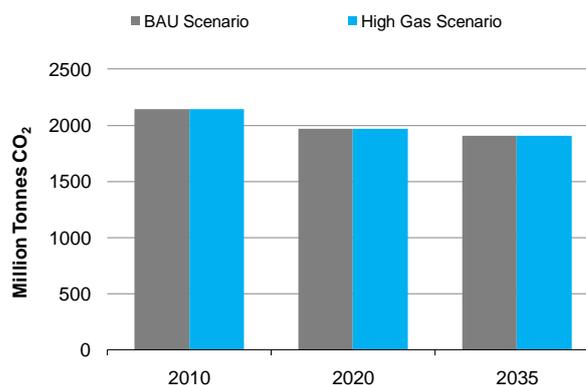


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario depends not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. The limiting factor for US gas production is the limited domestic consumption. Under BAU, domestic gas consumption reaches saturation in all sectors. Therefore, all additional gas production above BAU must be exported as LNG. Exports via pipeline are unlikely since both the neighboring economies of Mexico and Canada are net exporters of gas to the US. Owing to the large capital investment for LNG, the long development horizon and the lack of existing infrastructure, gas production does not materially increase under the High Gas Scenario until after 2020. Increasing gas production would seek to boost US economic growth.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Gas has roughly half the CO<sub>2</sub> emissions of coal per unit of electricity generated. Since the US electricity sector has no room for further gas utilization there is no domestic benefit in reducing CO<sub>2</sub> emissions. However, significant CO<sub>2</sub> emissions reductions exist for LNG importing economies within APEC (see China High Gas Scenario). With a more abundant LNG supply at no additional cost there is much potential for coal to gas switching in the power sector for the LNG importing economies within APEC. Figure US10 shows the CO<sub>2</sub> emissions under the High Gas Scenario are unchanged from BAU.

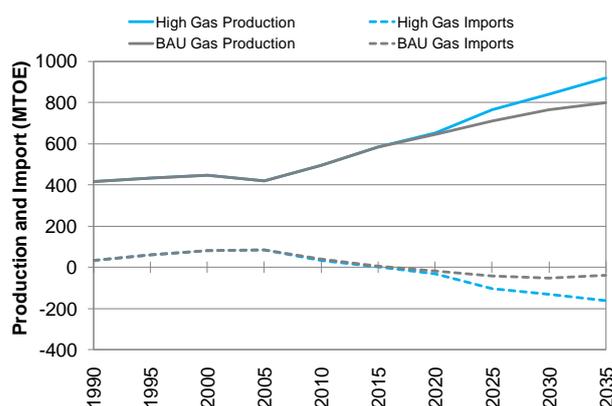
Figure US10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation



Source: APERC Analysis (2012)

Figure US11 shows the High Gas Scenario production and imports. Gas exports increase from 30 Mtoe under BAU to around 155 Mtoe by 2035.

Figure US11: High Gas Scenario – Production and Imports



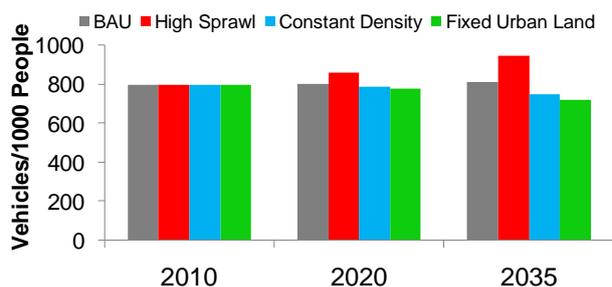
Source: APERC Analysis (2012)

### ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure US12 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level of vehicle saturation in long term vehicle ownership. Under BAU, US vehicle ownership is near saturation. The change in vehicle ownership under the different urban planning scenarios is significant.

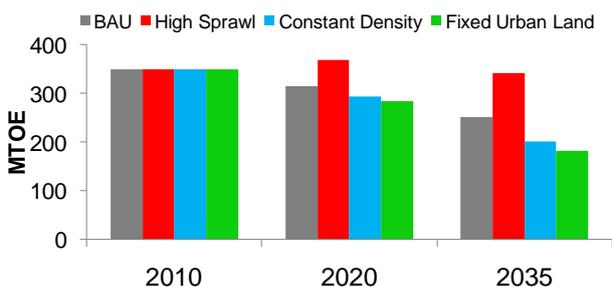
**Figure US12: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure US13 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact on oil consumption in the light vehicle fleet is compounded by a change in urban living and in the distances vehicles travel. In compact cities, travel distances per vehicle are typically lower than in sprawling cities.

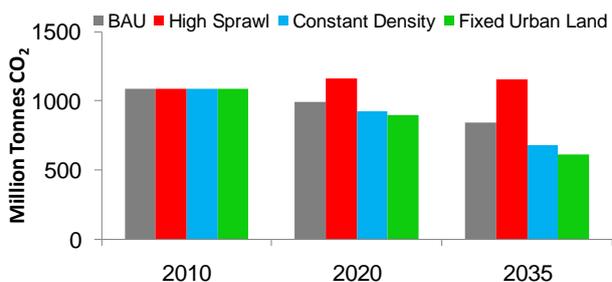
**Figure US13: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure US14 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases.

**Figure US14: Urban Development Scenarios – Light Vehicle Wheel-to-Tank CO<sub>2</sub> Emissions**



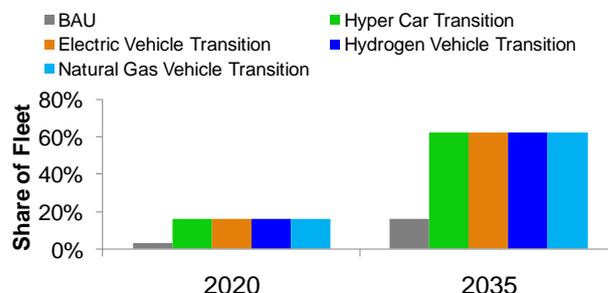
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure US15 shows the evolution of the vehicle fleet under BAU and the four ‘Virtual Clean Car Race’ scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 62% compared to about 16% in BAU scenario. The share of conventional vehicles in the fleet is thus only about 38%, compared to about 84% in BAU scenario.

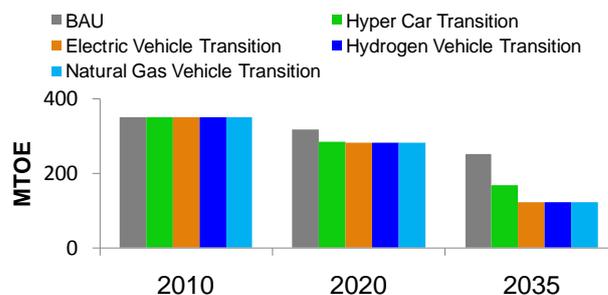
**Figure US15: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**



Source: APERC Analysis (2012)

Figure US16 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 34% by 2035—even though these highly-efficient vehicles still use oil.

**Figure US16: Virtual Clean Car Race – Light Vehicle Oil Consumption**

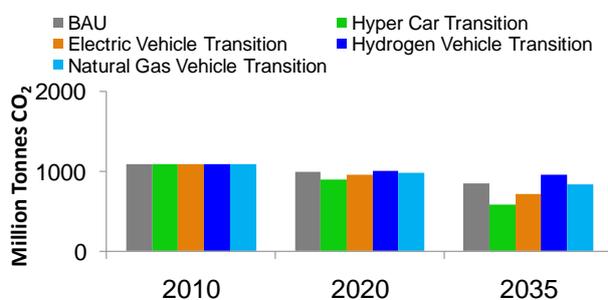


Source: APERC Analysis (2012)

Figure US17 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In the US, the Hyper Car Transition scenario is the clear winner in terms of CO<sub>2</sub> emissions savings, with an emissions reduction of 31% compared to BAU in 2035. In addition, both Electric Vehicle Transition and Natural Gas Vehicle Transition scenarios offer savings in emissions of 15% and 2% respectively compared to BAU in 2035. In contrast, the Hydrogen Vehicle Transition scenario increases emissions 12%. This is principally because hydrogen production from steam methane reforming (from hydrocarbon fuels) has high emissions from the fuel production and distribution process. (To facilitate fair comparisons, the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios assumed no additional non-fossil utilization for their energy production.)

**Figure US17: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

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# VIET NAM

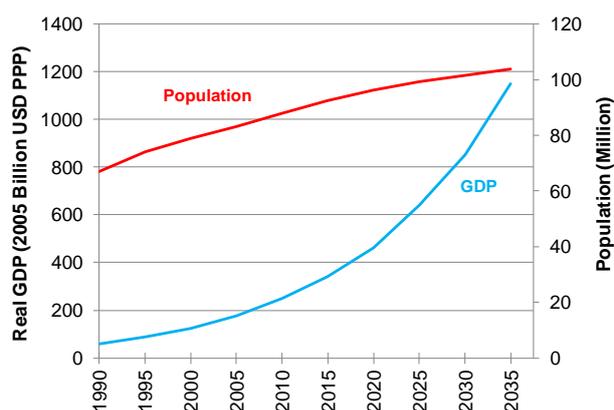
- Viet Nam's final energy demand is expected to grow at an average annual rate of 3.5% over the outlook period, from 55.6 Mtoe in 2009 to 138.7 Mtoe in 2035. The 'other' sector (consisting of the residential, commercial and agricultural subsectors) will account for the biggest share of the total demand (57%) in 2035.
- Viet Nam is expected to become a net importer of energy from 2020 and the economy's energy import dependency is projected to reach 54% by 2035.
- CO<sub>2</sub> emissions from fuel combustion are projected to reach 466 million tonnes of CO<sub>2</sub> by 2035.

## ECONOMY

Viet Nam is located in South-East Asia. It shares borders with Cambodia and the Lao People's Democratic Republic (Lao PDR) to the west, and China to the north; while to the east and south it borders the Gulf of Tonkin, the Eastern Sea (also known as the South China Sea) and the Gulf of Thailand. Viet Nam's total land area is 330 958 square kilometres, spread out in an elongated 'S' shape; this also gives it an extensive marine exclusive economic zone along its 3260-kilometre coastline.

Viet Nam lies in the tropical monsoon zone. The typical features of this zone include warmth, humidity and abundant seasonal rainfall. In the north there are four seasons, while in the centre and in the south it is hot all year round with just two seasons, rainy and dry.

**Figure VN12: GDP and Population**



Sources: Global Insight (2012) and APERC Analysis (2012)

In 2010, Viet Nam's population was 87.9 million. Economic growth and rising household incomes mean the use of air conditioning for cooling interiors is growing in Viet Nam. In 2012 it is common in commercial buildings and also in private urban homes, and the demand for air conditioning is expected to continue to increase over the outlook period. In contrast, the use of biomass fuels for

cooking in rural areas (and for home heating in mountainous areas) will decrease.

Market-oriented reforms since 1986 and rapid economic development have transformed the economy of Viet Nam over recent decades. The economic growth rate for the period 1990–2010 was an annual average of 7.4%, with GDP increasing from USD 60 billion in 1990 to USD 250 billion in 2010 (figures in 2005 USD PPP).

In 2010, Viet Nam had an income per capita of about USD 2850 (in 2005 USD PPP). The government has set a target of GDP growth between 6.5% and 7.0% per year over the period 2010–2015 (PMVN, 2011b). The government also expects population growth to be under 1.2% over the same period. This outlook, which takes into consideration the current global economic context and Viet Nam's future economic prospects, projects an average annual GDP growth rate of 6.3% over the outlook period, and a population growth rate of 0.7% per year over the same period, with the total reaching 104 million people by 2035. The rate of urbanization growth is higher, at an average annual rate of 1.9%; this means over 50% of the population is expected to be living in urban centres by 2035. GDP per capita (in 2005 USD PPP) is expected to exceed USD 11 000 by 2035, comparable to the equivalent figure for Malaysia in 2005 (USD 11 570).

Viet Nam's economy is dependent on exports and on agriculture, including fisheries. Major export products include coal, crude oil, textiles, footwear, rice, fish and agricultural products, and electronic products (GSO, 2009, p. 459i). The sector making the highest contribution to GDP is industry, at over 35% of the total share in 2009.

The industry sector is expected to grow quickly over the outlook period, based on growth in food processing, iron and steel, and textiles and leather. Most industry is concentrated in and around Viet Nam's big cities, including Ho Chi Minh City, Dong Nai, Bien Hoa, Hai Phong, Quang Ninh and

Ha Noi. While energy use for industry will grow at a slower rate over the outlook period than it did during 2000–2009, energy-intensive industries, such as iron and steel factories and cement and chemical plants, are still expected to account for nearly 40% of the economy's total energy use in the industry in 2035.

The economy relies heavily on its road networks, which are used for 80% of passenger trips and more than half of the freight movements. Other transportation modes in use are rail and waterways.

Most public transport services in Viet Nam are privately owned and operated, using buses, taxis, and motorbike taxis. In 2009, there were 23 million motorbikes in the economy, compared to 0.8 million cars. However, car ownership is expected to increase much more rapidly than motorbike ownership over the outlook period — the share of motorbikes in the total vehicle fleet will probably be drastically reduced by 2035. Most car ownership will be private, as the Vietnamese Government is phasing out the purchase of new cars and imported second-hand cars for government use.

Traffic congestion is already an issue in urban areas, particularly in Ha Noi and Ho Chi Minh cities, where the existing road networks do not have the capacity for the growing traffic volumes. To address congestion and also to reduce CO<sub>2</sub> emissions, the government of Viet Nam has developed policy to promote the use of public bus systems in these cities. At the same time, mass transit systems including subways and sky trains are being constructed in stages in both Ha Noi and Ho Chi Minh. Most of the systems are expected to be operational by the end of the outlook period.

The government's long-term aim is to improve the land-based connection between Ha Noi and Ho Chi Minh cities, and in doing so to reduce the air traffic between them. A high-speed railway between the two cities has been proposed—a revised plan is to be submitted to the National Assembly after the initial proposal was rejected on cost reasons. The revised proposal will prioritise the construction of two segments: Ho Chi Minh–Nha Trang, and Ha Noi–Vinh (not the entire Ha Noi–Ho Chi Minh route proposed initially). The intent is to shift traffic to rail from road, and therefore reduce the economy's demand for petroleum fuel.

## ENERGY RESOURCES AND INFRASTRUCTURE

Viet Nam has diverse fossil energy resources, including oil, gas and coal, as well as renewable energy resources such as hydro, biomass, solar and geothermal. Natural gas and crude oil are found

mainly offshore in the southern region, while coal reserves (mostly anthracite) are located in the north.

Over the period 1995–2010, oil production and exports grew at an average annual rate of 10.4%. In 2012, Viet Nam has 14 oil-producing fields: Bach Ho, Rong, Dai Hung, Rang Dong, Ruby, Emerald, Su Tu Den, Bunga Kekwa, Bunga Raya, Bunga Tulip, Ca Ngu Vang, Phuong Dong, Song Doc, and Cendor. Five of these are new fields, explored only since 2008. Most oil exploration and production activities occur off the southeast coast in the Cuu Long and Nam Con Son basins. Before 2009, Viet Nam did not have its own refinery, so all crude oil production was exported and petroleum products were imported. However, since February 2009, a refinery with a capacity of about 150 000 barrels per day has been in operation in Quang Nam province. The refinery provides around 6.5 million tonnes of petroleum products annually for domestic consumption (Petrovietnam, 2012).

Gas resources are found in many parts of Viet Nam, with the largest found in offshore basins. As well as the large gas fields discovered in the Cuu Long and Nam Con Son basins, there is the Malay–Tho Chu basin offshore of the southwest region and the Song Hong basin in the north. The Cuu Long basin is one of the developed natural gas production areas, with most of its gas produced in association with crude oil production (Petrovietnam, 2012).

Natural gas demand in Viet Nam, especially for electricity generation, has increased rapidly since 1995, and it is expected to continue to rise over the outlook period. At the same time, the current proved reserve is not very large compared with the reserves estimated in neighbouring economies, and local oil and gas experts' studies show a big gas discovery is unlikely. The reports suggest only the current annual supply of about 7–8 billion cubic metres (6.3–7.2 Mtoe) is assured from 'proven plus probable' (2P) reserves. To achieve annual production over 20 billion cubic metres (18 Mtoe) after the year 2020 will require the 'proven plus probable plus possible' (3P) reserves to move into the 'proven' category by means of further successful exploration and development (World Bank, 2010). Overall, natural gas imports are expected to be required after 2020. Unconventional gas has not been considered in Viet Nam so far.

Viet Nam has two large coalfields located in the north, in Quang Ninh province and the Red River Delta. As at the end of 2008, Viet Nam's coal reserves excluding peat were estimated at 6141 million tonnes. Of this geological reserve, 70%

is anthracite, and is deposited in Quang Ninh province. Most of the remainder is sub-bituminous coal, including deposits of 1580 million tonnes (26%) in the Khoai Chau region of the Red River Delta, and 96 million tonnes of fat coal deposits, which are used for making coke (MOIT and Vinacomin, 2008). In 2009, Viet Nam exported over 20 million tonnes of coal, a record amount, and exports made up nearly 50% of the coal industry's sales that year. Major export destinations included China, Japan, Korea, Chinese Taipei, Thailand and India.

Coal production changes expected in the outlook period include a shift from open cut mining to underground mining, as the producing coal seams in the Quang Ninh mines get deeper. In addition, the commercial development of the sub-bituminous coal of the Red River Delta is scheduled to begin after 2015. However, while the volume of coal production will keep growing, to reach 75 million tonnes by 2030 and will plateau from 2030 onwards, this will not match the increasing coal demand. Viet Nam is expected to import coal after 2020 under business-as-usual (BAU) conditions.

The rapid expansion of Viet Nam's economy between 1995 and 2009 meant electricity demand increased dramatically in the same period. The average annual rate of growth between 1995 and 2009 was 13%: the 2009 electricity demand of 83 200 GWh was nearly six times greater than the 1995 figure of 14 648 GWh. Peak demand increased more than four times during this period, rising to 13 800 MW compared to 3200 MW in 1995. The potential peak demand was even higher than reported, as power shortages led to load shedding and cuts in electricity supply during peak hours.

In 2009, power generation in Viet Nam was based on these sources: gas (43%), hydro (32%), coal (23%) and oil (2%). The construction of new electricity plants using nuclear, hydro and renewable energy sources is constrained by the availability of resources and construction sites and by high generation costs. As a result, the relatively more flexible resources of coal and natural gas make up the majority of the electricity generation mix throughout the outlook period—accounting for more than 70% of generation between them.

Some development of hydro and nuclear power plants will still take place to meet the demand growth and this will contribute to the projected five-fold increase of electricity supply by 2035. However, the limits to hydro development, and the long lead-time required to mobilize technology and funding for nuclear plant construction, mean the majority of the electricity demand increase in the outlook period will

be supplied by thermal generation, based on coal and natural gas.

## ENERGY POLICIES

The key points of Viet Nam's National Energy Development Strategies include:

- Diversified and effective exploitation of domestic natural resources, in combination with a reasonable import–export balance, with the gradual reduction of primary energy exports, conserving fuels and ensuring energy security for the future.
- Development of energy in line with natural resource protection and environmental protection, ensuring sustainable development of the energy sector.
- Increasing the share of rural households using commercial energy to 80% by 2020. By 2020, 100% of rural households will have access to electricity.
- Increasing the share of renewable energy in the total commercial primary energy supply to 5% by 2025 and to 11% by 2050.
- Reducing dependence on energy imports.
- Nuclear power development plan.
- Enhancing international cooperation in the energy sector (PMVN, 2007).

To reach the targets set for increasing the share of renewable energy sources in power generation, the government of Viet Nam has, since 2008, been developing policy to support renewable energy use. Government documents in this area include the Decision by the Minister of Industry and Trade on “Regulation on avoided cost electricity tariff schedule and standard power purchase agreement” (MOIT, 2008), and the Decision by the Prime Minister on “Mechanism for supporting wind power development” (PMVN, 2011a). The key elements of the decision on wind power development are the provision of incentives for capital investment, and provisions about related land use, transmission fees and electricity tariffs.

As an agriculture economy, Viet Nam has good biomass resources, including fuel wood, waste residues from crops, and other organic wastes. However, currently these sources are mostly used as non-commercial energy for households. To better harness this potential, the government is actively encouraging the production of biomass-based electricity. A number of rice-husk power plants are under development in the Mekong River delta, with support from local authorities. The use of solar

power, however, is limited in Viet Nam by high development costs, and is restricted to a few projects supported by the government.

The development of nuclear power has been actively pursued in Viet Nam since the mid 1990s. It formed an important part of the National Energy Research Program for 1995–2000, run by a group of organizations including the Institute of Energy (IE), the Ministry of Industry and Trade (MOIT), Atomic Energy Research Institutes, and the Ministry of Science and Technology (MOST), with the assistance of foreign companies and the governments of Japan, France, Korea, Canada, and Russia. Through this program, a number of engineers, researchers and policymakers from Viet Nam have engaged in study and offshore training in various areas related to nuclear power. The research program concluded that nuclear power needed to be included as a key item in the economy's energy policy development in coming years. Since 2000, the government has been developing legal and policy frameworks, and technical and human infrastructures, to facilitate the development of nuclear power. These include the Atomic Energy Law (Government of Viet Nam, 2008), the “Strategy for utilization of atomic energy for peace in Viet Nam” (MOST, 2006), and a pre-feasibility study and a human resource development program for the first nuclear power plant (MOIT and IE, 2005 and 2009; MOST, 2006).

These preparations have laid the groundwork for the first unit of Viet Nam's first nuclear power plant, scheduled to begin operations in 2020. The share of nuclear power in the economy's energy mix is then expected to increase gradually, to reach 20–30% of the total electricity production by 2050. However, after the Fukushima Daiichi Nuclear Power Plant accident in Japan, safety issues in the development and operation of nuclear power plants, already a high priority for Viet Nam, now mean the program's timeframe is under review.

The Vietnamese Government has recognized the need to improve energy efficiency in parallel with its efforts to develop energy resources. In 2006, the Ministry of Industry and Trade (MOIT) launched the National Energy Efficiency Program (VNEEP) for the period 2006–2015. This is the most comprehensive and effective of a variety of initiatives undertaken in this area since 1995 (PMVN, 2006b). VNEEP sets targets to reduce the economy's total energy consumption by 3–5% annually from 2006 to 2010, rising to 5–8% annually during 2011–2015 (compared to BAU levels). The program includes six packages with 11 actions (projects) covering key areas of energy efficiency. These key areas include: the legal framework; education and information dissemination;

high-efficiency equipment and appliances; energy efficiency and conservation in industry; and the building code. A State Steering Committee (chaired by the MOIT) has been established, to oversee the implementation and monitoring of the program alongside the Energy Efficiency and Conservation Office, which has the role of coordinating the contribution of other governmental organizations (PMVN, 2006b).

There are no specific policies promoting the use of unconventional vehicle fuels (such as LPG, CNG, electricity and bio-fuel). In 2012, 100% of road transport fuels are oil-based, and are expected to remain so until 2035.

Viet Nam is in the process of reducing some of its fuel price regulations and subsidies. At times the government has required the Vietnam National Coal Mineral Industries Group (Vinacomin) to supply coal for power generation at below cost price, and oil and gas prices are also regulated by the government. While the coal subsidy has supported the development of industries using coal-based power, it also affects Vinacomin's profit and re-investment levels. The government has begun the gradual reduction of regulation of the domestic coal price, and is preparing a strategy for the gradual removal of subsidies for coal used in power generation.

The Petrovietnam Oil and Gas Group (PVN) is a government-owned company. Its functions include implementing sector management on behalf of the government, investing in gas pipelines, negotiating Product Sharing Contracts (PSCs) with exploring and producing companies, as well as monitoring those contracts. PVN is made up of four businesses, which together hold 100% of the company's assets: the Petroleum Exploration and Production Corporation, the Gas Corporation, the Electricity Production and Trading Corporation, and the Oil Refining and Petrochemical Corporation. PVN also encompasses other companies, enterprises and training organizations.

Viet Nam's gas and oil upstream sector is open to all, while the downstream functions such as transmission, distribution, and marketing are almost all within the PVN monopoly. Oil and gas production is carried out by PVN and private companies, including foreign companies and joint ventures with PVN, but all are required to sell through PVN.

The Electricity Law sets out the key principles for change in the power market (PMVN 2006a). It established the Electricity Regulatory Authority of Viet Nam (ERAV) to assist the Minister for Industry and Trade in implementing regulatory activities in the

electricity sector; to contribute to a market that is safe and stable, and provides a high-quality supply of electricity; to foster the economical and efficient consumption of electricity; and to uphold the equity and transparency of the sector in compliance with the law. Under this legislation, Viet Nam's power market is to develop in three stages:

- Level 1 (2005–2014): a competitive generation power market will replace the current monopoly and subsidized power
- Level 2 (2015–2022): the establishment of a competitive wholesale power market
- Level 3 (after 2022): the realization of a competitive electricity retail market.

Electricity of Vietnam (EVN) is one of the important players in these changes, in its role coordinating the development, management and operation of the economy's electric power industry assets. There are also Build-Operation-Transfer (BOT) and Independent Power Producer (IPP) schemes run in partnership with private investors. In 2009, 32% of the electricity supply system in Viet Nam was owned by companies other than EVN. In terms of electrification, 95.5% of villages in rural areas have access to electricity (GSO, 2011).

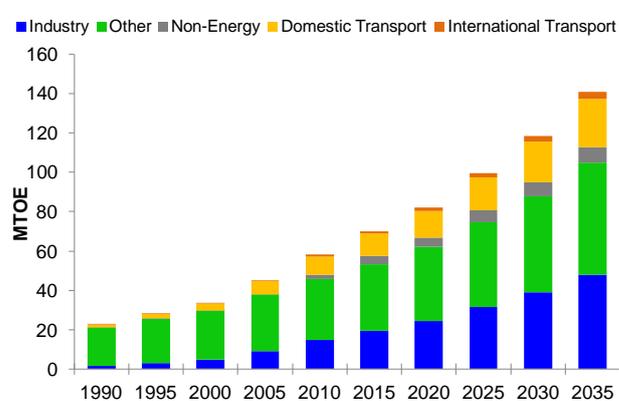
Work to enhance international cooperation in the energy field has included numerous agreements and projects that have been established and implemented within a framework of cooperation at a regional level. These include the ASEAN Power Grid, Trans-ASEAN Gas Pipeline, and Regional Power Trade in the Greater Mekong subregion. Viet Nam also has bilateral agreements on energy trade with neighbouring economies. In 2000, the governments of Viet Nam and Lao PDR signed an energy cooperation accord. Under this accord, Viet Nam will import about 2000 MW of electricity from Lao PDR (APEREC, 2009). The governments of Viet Nam and Cambodia have also signed an energy cooperation agreement, under which Viet Nam has supplied 80–200 MW of electricity to Cambodia via a 220 KV transmission line since 2009 (APEREC, 2009). In the future, when Cambodia builds hydro power plants and starts participating in the regional electricity market, Viet Nam will in turn buy electricity from Cambodia. In 2009, Viet Nam bought over 4.1 billion KWh of electricity from China and this annual amount will continue to increase. By 2020, a 500 KV transmission line between the two economies will be completed. Similar cooperative activities are underway in the coal, oil and gas sectors.

## BUSINESS-AS-USUAL OUTLOOK

### FINAL ENERGY DEMAND

Based on our business-as-usual (BAU) assumptions under the current economic conditions, total final energy demand for Viet Nam will continue to rise at an average annual rate of about 3.6% over the outlook period. This is less than the projected GDP growth for the economy. As a result, the total final energy demand in 2035 will reach about 140 Mtoe, which is a more than two-fold increase on 2010 levels. Energy consumption will increase in every sector of the economy, including the residential and commercial sectors, which are influenced by growing modernization within Viet Nam. The strongest growth, however, is in the industry and transport sectors.

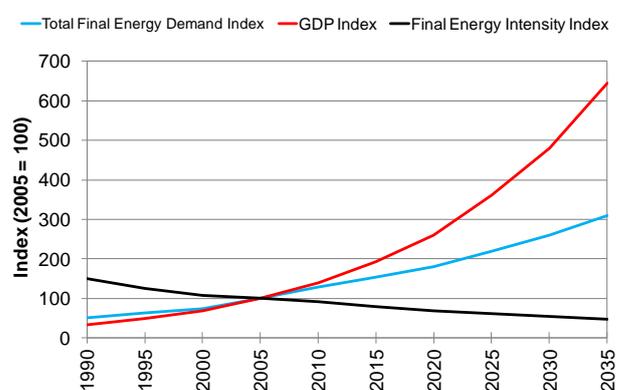
Figure VN13: BAU Final Energy Demand



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

By the end of the outlook period, oil is expected to represent the largest share of the final energy demand (34%), followed by electricity (24%) and coal (22%). Between 2010 and 2035, the consumption of gas is projected to grow the fastest, at an average annual rate of 7%. Final energy intensity is expected to decline by about 52% between 2005 and 2035.

Figure VN3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

## Industry

Industry is the sector that will consume the third largest amount of energy (after the Other and Non-Energy sectors) in Viet Nam by the end of the outlook period, accounting for 35% of the total final energy consumption in 2035. This is higher than the sector's 25% share in 2010.

Energy demand in the industry sector is projected to grow at an average annual rate of 5.0% until 2035, reflecting the rapid growth of Viet Nam industry generally. Viet Nam's heavy industry is dominated by iron and steel, and non-metallic minerals. However, the growth in heavy industry's energy demand will be significantly slower than in 2000–2009. This is due to the removal of the electricity price subsidies after 2015 and to increased regulation to reduce environmental pollution. The energy demand growth rate for other industries is expected to match that in the 2000–2009 period.

The industrial use of gas is projected to increase from 0.3 Mtoe in 2010 to 1.8 Mtoe in 2035, which at 7.3% is the fastest annual growth rate for fuels.

## Transport

The share of the final energy demand taken up by the transport sector (includes both international and domestic transport sectors) is expected to increase over the outlook period, from 17.8% in 2010 to 20% in 2035. It will increase at an average annual rate of 4.1% over this period.

After 2000, vehicle ownership in Viet Nam began to rapidly increase; however, the motorbike will remain the most popular means of passenger transport. Over the outlook period, the growth in motorbike ownership is expected to slow, peaking at 27 million units in 2030. In contrast, the ownership of four-wheel vehicles will grow significantly to 2035, as incomes rise and the road infrastructure improves.

Because there are no government incentives to switch to alternative fuels and vehicles, the demand for conventional fuel for transportation, such as diesel, gasoline and fuel oil, is expected to continue rising.

## Other

The energy used in the 'other' sector (which includes the residential, commercial and agriculture subsectors) is expected to increase from 31 Mtoe in 2010 to 57 Mtoe in 2035, rising at an average annual rate of 2.4%. This includes a high growth in the demand for electricity (6.5%), supported by strong GDP growth, rising household incomes and high rates of urbanization during the outlook period.

## PRIMARY ENERGY SUPPLY

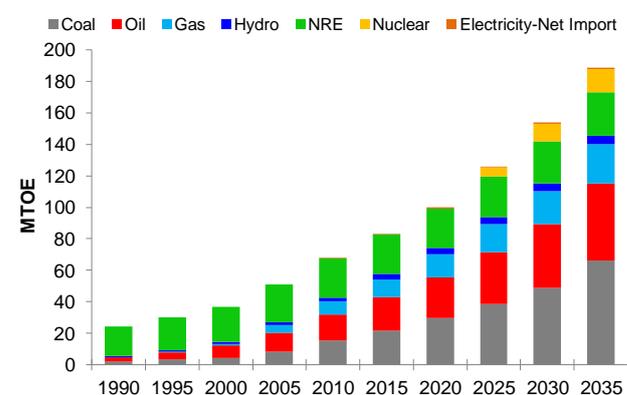
Viet Nam's primary energy supply is projected to increase almost three-fold over the outlook period, from 68 Mtoe in 2010 to about 188 Mtoe in 2035. This is based on an average annual increase of 4.2%. The proportion of non-commercial energy sources (biomass such as firewood) in the mix will decrease gradually. In 2010, non-commercial energy sources made up 37% of the primary energy supply; in 2035 they will provide just over 15%, as rising household incomes and the shift to urban centres prompts a shift to commercial energy sources.

Since 1990, Viet Nam has been a net energy exporter, with crude oil and coal as its main energy exports. However, from 2020 Viet Nam is expected to become a net importer of energy, as a result of its high energy demand growth and the limitations on available energy resources. The economy's oil import dependency is expected to start from 2014, reaching 66% in 2035.

The 2035 petroleum product demand in Viet Nam is forecast to be three times greater than the current level, and this demand will not be able to be met from domestic resources. In addition, the revenue from crude oil exports is diminishing, while the cost of energy imports is increasing. This means it is crucial for Viet Nam to use its indigenous resources as efficiently as possible and to minimize its imports.

Viet Nam is expected to reduce primary energy intensity by nearly 43% between 2005 and 2035—from 286 tonnes of oil equivalent (toe) per unit of GDP (in 2005 USD million PPP) to 164 toe per unit of GDP.

Figure VN4: BAU Primary Energy Supply



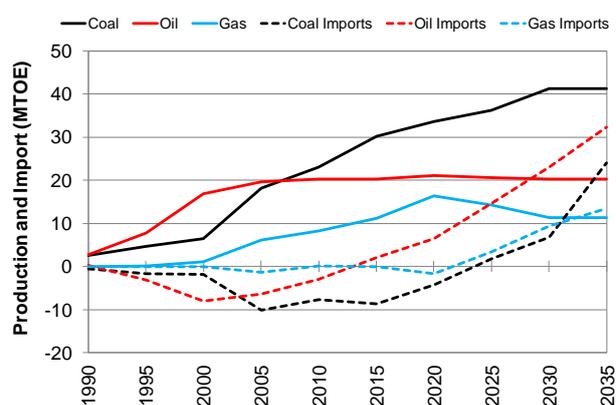
Source: APERC Analysis (2012)

Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Viet Nam's first oil refinery successfully started production in early 2009. A second refinery with the same capacity is expected to be in action by 2015. This outlook also assumes a third refinery, with a

150 000 barrel per day capacity, will start operations after 2020. In the final decade of the outlook period, 20–25 million tonnes of domestic petroleum products from the new refineries (accounting for about 50% of total supply) should be reaching the market. This will significantly contribute to the reduction of petroleum product imports to Viet Nam.

Figure VN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Coal will replace oil to form the largest share of the total primary energy supply. Coal demand growth will be driven mainly by the rapid development of the electricity and industry sectors, accounting for 35% of primary energy supply in 2035. After 2020, coal and natural gas demand are expected to exceed indigenous supply.

Oil will make up the second largest share of the primary energy supply, accounting for 26% in 2035. It is mainly used in the transport and industry sectors. In 2009, Viet Nam was an exporter of crude oil, but a net importer of oil products. As oil reserves decline over the outlook period, Viet Nam's oil import dependency is expected to increase to 66% in 2035.

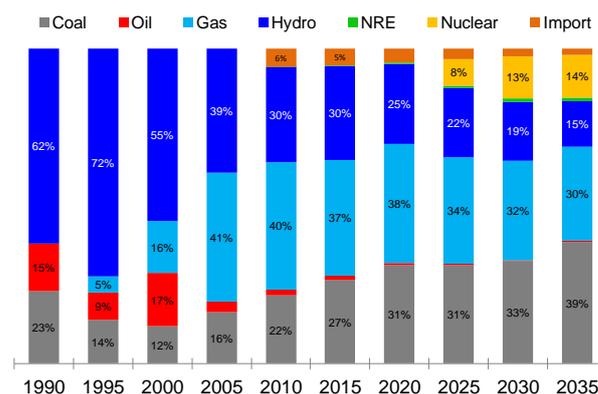
Electricity imports are expected to increase by 2020 and will account for 0.4% of the primary energy supply by 2035.

Excluding large-scale hydro, other types of renewable energy such as mini-hydro, wind, biomass, geothermal, and municipal solid waste landfill gas, will continue to be promoted. Together they will contribute 15% of the primary energy supply in 2035. Nuclear energy—based on it coming online after 2020—is expected to provide 8% of the total primary energy supply in 2035.

## ELECTRICITY

The current high electricity elasticity to GDP (1.9 in the period 2005–2010) is expected to drop to 1.1 by 2035. The electricity demand forecast in the government's Master Plan on Power Development (MOIT and IE, 2011) is substantially higher than in this APERC outlook—the differences between our analysis and the Vietnamese Government's projections can be explained by our expected drop in electricity elasticity.

Figure VN6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)  
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

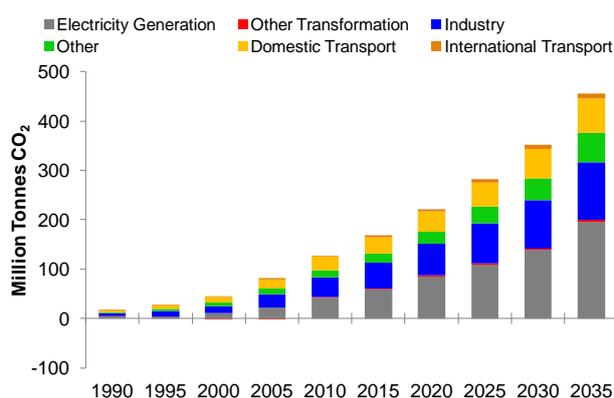
Plans for two nuclear power plants with a total capacity of 2000–4000 MW in Ninh Thuan province, in central Viet Nam, are currently at feasibility study stage. This BAU projection assumes the nuclear power plants will have started commercial operations by 2022. In 2035, the sources for electricity generation in Viet Nam are expected to be, in descending order, coal, gas, hydro, nuclear, renewable energy and fuel oil.

Electricity generation is projected to increase at an average annual rate of 6.1%, reaching 409 TWh in 2035. Over the outlook period, the hydro share of electricity production will decrease considerably, from 30% to 15%, as most potential locations for big and medium hydro plants become fully developed. By contrast, coal-fired generation will substantially increase, and will have the biggest share in 2035 (39%). The share provided by gas-fired plants is projected to decrease to 30% by 2035. Meanwhile, the nuclear share will increase from zero in 2009 to 14% in 2035. In addition, as the government continues to pursue its goal of increasing the use of domestic resources, new renewable energy sources (NRE) are expected to contribute to electricity generation, especially in remote areas where connection with the grid is not economically feasible. NRE's share will increase from zero in 2009 to 1% in 2035.

### CO<sub>2</sub> EMISSIONS

Viet Nam is currently one of the lowest per capita CO<sub>2</sub> emitters in APEC; 2010 levels were 1.5 tonnes of CO<sub>2</sub> per person. CO<sub>2</sub> emissions from fuel combustion are projected to grow at an average annual rate of 5.2% over the outlook period, reaching about 466 million tonnes of CO<sub>2</sub> in 2035. Emissions are expected to increase to relatively high levels as Viet Nam industrializes and the economy uses more carbon-intensive energy sources. This particularly applies to coal used for power generation.

Figure VN7: BAU CO<sub>2</sub> Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table VN1 suggests the growth in Viet Nam’s CO<sub>2</sub> emissions from fuel combustion is driven largely by economic growth, moderated by the declining energy intensity of GDP (energy efficiency measures).

Table VN1: Analysis of Reasons for Change in BAU CO<sub>2</sub> Emissions from Fuel Combustion

	(Average Annual Percent Change)				
	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO <sub>2</sub> Intensity of Energy	5.5%	3.2%	1.4%	1.4%	1.0%
Change in Energy Intensity of GDP	-2.3%	-0.9%	-1.8%	-1.8%	-2.0%
Change in GDP	7.6%	7.0%	6.5%	6.4%	6.3%
Total Change	11.0%	9.4%	6.0%	5.9%	5.2%

Source: APERC Analysis (2012)

### CHALLENGES AND IMPLICATIONS OF BAU

Under BAU, Viet Nam’s energy outlook is reasonably positive, considering the domestic and global aspects of this economy. From 2010–2035, energy security and per capita GDP will increase, while the average annual growth rate of CO<sub>2</sub> emissions (at 5.2%) will be less than the GDP growth rate of 6.3%. This emission growth rate is also much lower than the recorded CO<sub>2</sub> emission growth rate during 1990–2009 (10.4%). However, there are still significant opportunities for improved environmental sustainability; particularly in the power generation, transportation and industry sectors.

### ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

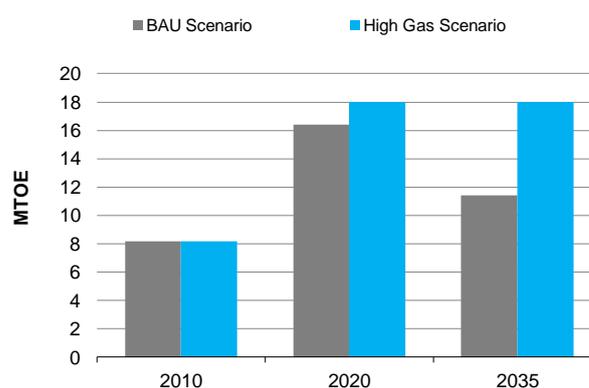
#### HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative ‘High Gas Scenario’ was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Viet Nam has no known reserves for unconventional gas, but there is potential for offshore deep water conventional natural gas. Realizing this potential requires a significant investment in exploration, production and transportation infrastructure. The High Gas Scenario for Viet Nam assumes sufficient investment is available for additional gas extraction from these new, more challenging gas fields.

Under these assumptions, the High Gas Scenario for Viet Nam assumed the production increase shown in Figure VN8, which is 57% higher than BAU by 2035. Production is expected to increase gradually to reach its peak in 2025. Due to the retirement of old, existing gas fields, production will begin to decrease again and will plateau from 2030 onwards at the 2020 production level.

Figure VN8: High Gas Scenario – Gas Production



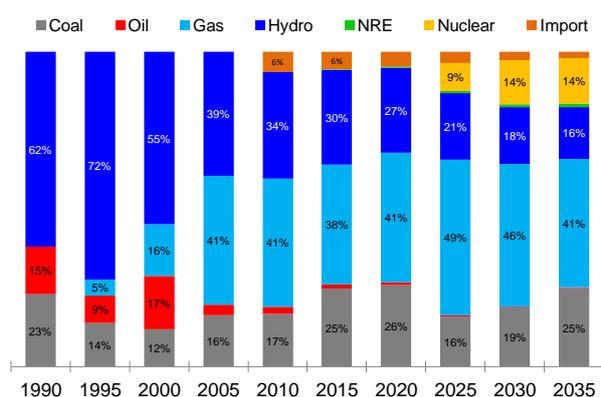
Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy’s own additional gas production, but also on the gas market situation in the APEC region. For Viet Nam, the additional gas production provides an opportunity to reduce local air pollution and CO<sub>2</sub>

emissions by burning less coal. Any remaining amount of gas will be exported via the Trans-ASEAN Gas Pipeline (TAGP).

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure VN9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph in Figure VN6. It can be seen that the gas share has increased by 11% by 2035, while the coal share has declined by 14%.

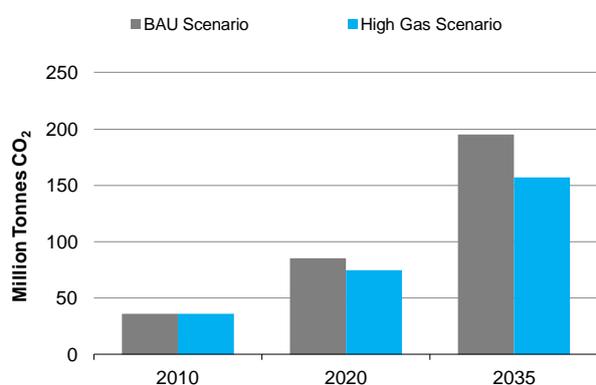
**Figure VN9: High Gas Scenario – Electricity Generation Mix**



Source: APERC Analysis (2012)  
Historical Data: World Energy Statistics 2011 © OECD/IEA 2011

A higher gas share in the electricity generation mix is projected to reduce the CO<sub>2</sub> emissions in electricity generation by 20% by 2035, since gas has roughly half the CO<sub>2</sub> emissions per unit of electricity generated of coal. Figure VN10 shows this CO<sub>2</sub> emissions reduction.

**Figure VN10: High Gas Scenario – CO<sub>2</sub> Emissions from Electricity Generation**



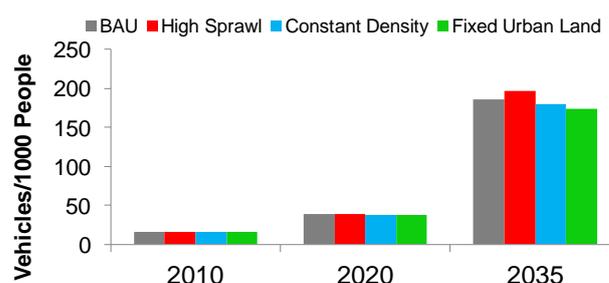
Source: APERC Analysis (2012)

## ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: ‘High Sprawl’, ‘Constant Density’, and ‘Fixed Urban Land’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure VN11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Since vehicle ownership is still well below saturation point in Viet Nam, the impact of urban planning on vehicle ownership is barely discernible in 2020, but by 2035 the difference between the four scenarios are more pronounced. In 2035, vehicle ownership will be about 6% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 7% lower in the Fixed Urban Land scenario.

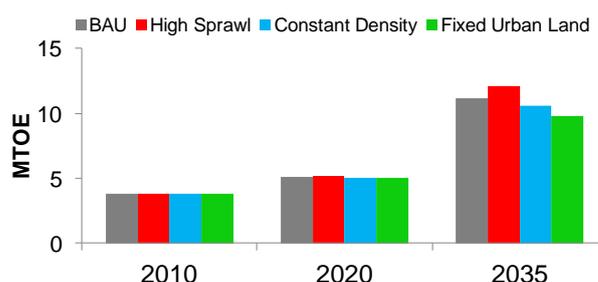
**Figure VN11: Urban Development Scenarios – Vehicle Ownership**



Source: APERC Analysis (2012)

Figure VN12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of urban planning on light vehicle oil consumption is relatively small and similar to that on vehicle ownership. Light vehicle oil consumption will be 8% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 12% lower in the Fixed Urban Land scenario.

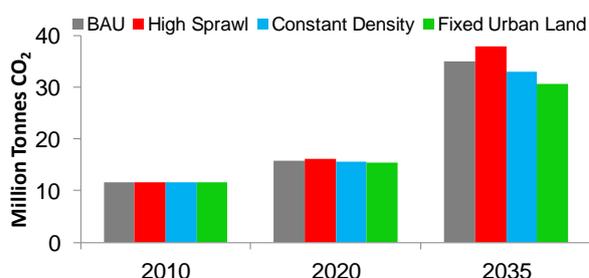
**Figure VN12: Urban Development Scenarios – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure VN13 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO<sub>2</sub> emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

**Figure VN13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO<sub>2</sub> Emissions**



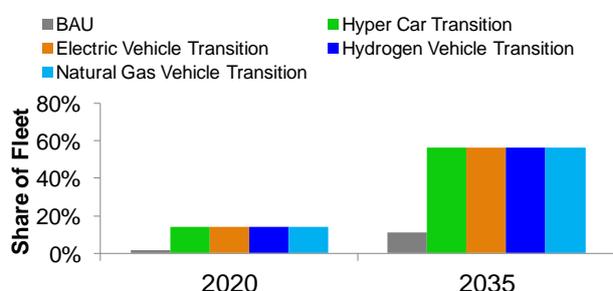
Source: APERC Analysis (2012)

**VIRTUAL CLEAN CAR RACE**

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: ‘Hyper Car Transition’ (ultra-light conventionally-powered vehicles), ‘Electric Vehicle Transition’, ‘Hydrogen Vehicle Transition’, and ‘Natural Gas Vehicle Transition’. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure VN14 shows the evolution of the four-wheel light vehicle fleet under BAU and the four alternative ‘Virtual Clean Car Race’ scenarios. By 2035, the share of alternative vehicles in the four-wheel fleet reaches around 53% compared to about 4% in the BAU scenario. The conventional vehicles in the fleet is thus only about 47% compared to about 96% in the BAU scenario.

**Figure VN14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet**

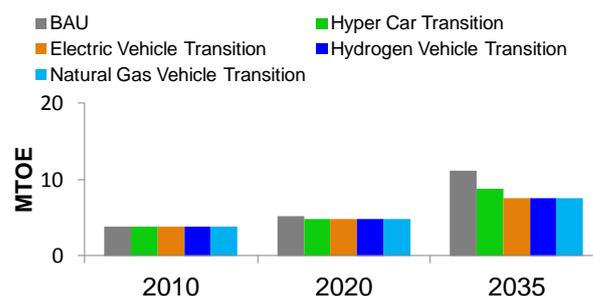


Source: APERC Analysis (2012)

Figure VN15 shows the change in all light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 32% in the Electric Vehicle Transition, Hydrogen Vehicle

Transition, and Natural Gas Vehicle Transition scenarios compared to BAU, as these alternative vehicles do not use oil. (In this graph, motorbikes are also included in the light vehicle fleet. Viet Nam is somewhat unique in that they will account for a significant share—about 35% of light vehicle oil consumption in 2035 under BAU. Motorbike energy demand does not change in the alternative vehicle scenarios.) Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—23% by 2035.

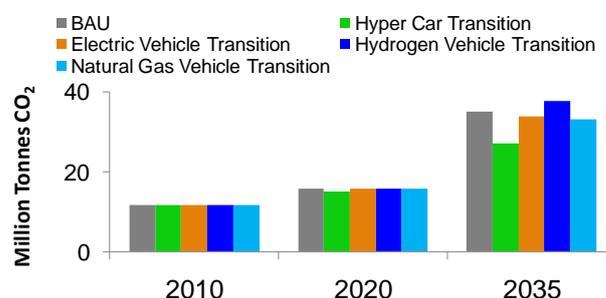
**Figure VN15: Virtual Clean Car Race – Light Vehicle Oil Consumption**



Source: APERC Analysis (2012)

Figure VN16 shows the change in light vehicle CO<sub>2</sub> emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO<sub>2</sub> emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emissions levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

**Figure VN16: Virtual Clean Car Race – Light Vehicle CO<sub>2</sub> Emissions**



Source: APERC Analysis (2012)

In Viet Nam, the Hyper Car Transition scenario is the clear winner with an emissions reduction of 22% compared to BAU in 2035. Both the Electric Vehicle Transition and Natural Gas Vehicle Transition scenarios offer less emissions reductions (3% and 5%, respectively). This is principally because

the marginal source for added electricity demand is coal-fired generation, which has an adverse impact on the emissions of electric vehicles. The Hydrogen Vehicle Transition scenario produces 8% more emissions compared to BAU in 2035. Higher emissions for this scenario can be attributed to the process of hydrogen production from steam methane reforming of natural gas.

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