A QUEST FOR ENERGY SECURITY IN THE 21ST CENTURY

RESOURCES AND CONSTRAINTS

ASIA PACIFIC ENERGY RESEARCH CENTRE

This report is posted on the Internet at
www.ieej.or.jp/aperc

Published by

Asia Pacific Energy Research Centre
Institute of Energy Economics, Japan
Inui Bldg. Kachidoki 16F, 1-13-3 Kachidoki
Chuo-ku, Tokyo 104-0054 Japan
Tel: (813) 5144-8551
Fax: (813) 5144-8555
Email: master@aperc.ieej.or.jp (administration)

APEC # 207-RE-01.2

ISBN 978-4-931482-35-7

Printed in Japan

FOREWORD

We are pleased to present the report, "A Quest for Energy Security in the 21st Century". The study is one of three research projects commenced in the year 2006. The objective of the study is to provide APEC economies with options for the enhancement of energy security and sustainable development. The principal findings of the study are highlighted in the executive summary of this report.

This report is published by Asia Pacific Energy Research Centre (APERC) as an independent study and does not necessarily reflect the views or policies of the APEC Energy Working Group or of individual APEC member economies. We hope that this report will serve as a useful basis for discussion and analysis among APEC member economies of the enhancement of energy security and sustainable in this century.

Kotaro KIMURA

President

Asia Pacific Energy Research Centre

ACKNOWLEDGEMENTS

We would like to thank all of those who worked hard on the project. The development of this report could not have been accomplished without the contributions of many individuals, both inside and outside of APERC.

We wish to express our appreciation to the APERC Conference and Workshop participants, namely Prof. Hoesung Lee of CEEK and Keimyung University (Korea), Ms. Linda Doman of the Energy Information Administration (United States), Dr. David Howell of Stanford University (United States), Dr. Rafael A. Neives of BBI International (United States), Dr. Donald Gautier of the USGS (United States), Dr. Sueo Machi, Former Commissioner, Atomic Energy Commission of Japan, Dr. Vladimir V. Saenko of the Ministry of Industry and Energy (Russia Federation), Mr. Gary Walker of the Department of Industry, Tourism and Resources (Australia), Mr. Rejean Casaubon of Natural Resources Canada , Dr. Weerawat Chantanakome of the ASEAN Centre for Energy, Prof. Thierry Lefevre of the Centre for Energy Environment Resources Development, and Prof. Nikolay I. Voropay of Energy Systems Institute (Siberian Branch, Russia Federation).

We also would like to thank members of the APEC Energy Working Group (EWG), APEC Expert Group on Energy Data and Analysis (EGEDA) and other government officials for their stimulating comments and assistance to the study.

APERC CONTRIBUTORS

PROJECT LEADER:

Narumon INTHARAK (Thailand)

PROJECT PARTICIPANTS:

Jupri Haji JULAY (Brunei Darussalam)
Satoshi NAKANISHI (Japan)
Tomoko MATSUMOTO (Japan)
Endang Jati MAT SAHID (Malaysia)
Alberto Gotardo ORMENO AQUINO (Peru)
Alicia Altagracia APONTE (United States of America)

EDITOR:

Alicia Altagracia APONTE

ADMINISTRATION SUPPORT

Sutemi ARIKAWA, Shohei OKANO, Sachi GOTO, Mizuho FUETA, and Yumiko NISHINO.

CONTENTS

List of tables

List of Figures

List of Abbreviations

ADB	Asian Development Bank
AEO	Annual Energy Outlook
APEC	Asia-Pacific Economic Co-operation
APERC	Asia Pacific Energy Research Centre
API	American Petroleum Institute
ASU	Air Separation Unit
AUS	Australia
Bcf	Billion cubic feet
BD	Brunei Darussalam
CAIR	Clean Air Mercury Rules
CBM	Coal Bed Methane
CCS	Carbon Capture and Sequestration
CDA	Canada
CDM	Clean Development Mechanism
CETREE	Centre for Education and Training in Renewable Energy and Energy Efficiency
CHL	Chile
CNG	Compresses Natural Gas
CO_2	Carbon dioxide
CT	Chinese Taipei
CTL	Coal to Liquids
DANIDA	Danish International Development Assistance
DoPED	Diversification of Primary Energy Demand
EE	Energy Efficiency
EIA	Energy Information Administration (USA)
EOR	Enhance Oil Recovery
FBC	Fluidised Bed Combustion
FGD	Flue Gas Desulphurisation
FSU	Former Soviet Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTL	Gas to Liquids
GW	Gigawatt (10^9 Watts)
HKC	Hong Kong, China
IEA	International Energy Agency
IAEA	International Atomic Energy Agency
IEO	International Energy Outlook
IGCC	Integrated Gasification Combined Cycle
IMF	International Monetary Fund
INA	Indonesia
IOC	International Oil Company
IPCC	International Panel on Climate Change
JPN	Japan
kW	Kilowatt (= 1,000 watts)
LNG	Liquefied Natural Gas
MAS	Malaysia
mbd	million barrels per day
MEOID	Middle East Oil Import Dependency
MEPS	Minimum Energy Performance Standards
Mt	Million tonnes
METI	Ministry of Economy, Trade and Industry
MEX	Mexico
Mtoe	million tonnes of oil equivalent
NEDO	New Energy & Industrial Technology Development Organization
NEI	Nuclear Energy Institute
NEID	Net Energy Import Dependency

NGL	Natural Gas Liquids
NGV	Natural Gas for Vehicle
NNP	Nuclear Power Plant
NOC	National Oil Company
NOID	Net Oil Import Dependency
NOx	Nitrogen Oxides
NRE	New and Renewable Energy
NZ	New Zealand
O&M	Operation and Maintenance
OPEC	Organisation of the Petroleum Exporting Countries
PE	Peru
PED	Primary Energy Demand
PES	Primary Energy Source
PNG	Papua New Guinea
PRC	People's Republic of China
PTM	Pusat Tenega Malaysia
PV	Photovoltaic
RE	Renewable Energy
R&D	Research and Development
ROK	Republic of Korea
RP	The Republic of the Philippines
RUS	The Russian Federation
SCO	Synthetic Crude Oil
SCR	Selective Catalytic Reduction
SIN	Singapore
SNCR	Selective non-Catalytic Reduction
SO_2	Sulphur Dioxide
SPR	Strategic Petroleum Reserve
TBD	Thousand Barrel per Day
Tcf	Trillion cubic feet
Tcm	Trillion cubic meters
THA	Thailand
toe	tonne of oil equivalent
TPES	Total Primary Energy Supply
TWh	Terawatt hour (one billion kilowatt hours)
US$	United States Dollar
USGS	United States Geological Survey
US	United States of America
VN	Viet Nam
WEO	World Energy Outlook

EXECUTIVE SUMMARY

Energy security is a major concern in the APEC region since energy demand growth is inevitable due to economic and population growth. As energy resources are scarce and subject to depletion, measures to deal with future demand and supply trends need to be developed among APEC member economies.

THE 4 A'S OF ENERGY SECURITY

ENERGY RESOURCE AVAILABILITY:

- Conventional oil, although depleting, will remain an important energy source. If all recoverable resources become available, the R/P ratio will extend from 41 years to 80 years. In addition, there is a significant non-conventional oil resource base, which could become part of the reserves base in the future. Oil sands, for example, have already become affordable.
- As for natural gas, it is more reliable than oil in terms of availability because gas resources have not been developed to the same extent as oil resources and they are more widely distributed. Non-conventional gas resources are also abundant. For example, tight sand gas, in the US, has already become an important gas supply source.
- Estimated coal reserves worldwide are large and therefore are expected to serve global needs well throughout this century.
- The NRE and hydro energy resource base is sufficient to cover the world's current primary energy consumption despite its specific physical constraints, such as weather dependence and low energy supply density. For example, solar/wind power plants have 1/500 the power generation density per square meter of fossil fuel/ nuclear power plants and 1/100 of hydro power plants. Therefore, NRE and hydro energy are affordable on a local scale, but not as a major energy supply resource.
- Similar to NRE and biofuels have supply capacity constraints; therefore, their potential role as a substitute for conventional fuels is limited. Nevertheless, its importance is growing as a result of energy supply security concerns. Further technology development will help reduce these limitations in the future.

ACCESSIBILITY BARRIERS:

- Oil supply security is now jeopardised by accessibility barriers, particularly geopolitical factors which could turn into reality as early as the next few decades when non- OPEC supply fails to meet growing global demand. It is therefore essential for us to take this risk seriously, even though it is difficult to predict the timing of global oil peak arrival with a reasonable accuracy because of unreliable reserves and resource estimates data.
- Accessibility of natural gas depends largely on huge infrastructure investments and long term sales contracts. Even though gas is at a disadvantage to oil in terms of accessibility, it is manageable because it is not as fundamental of a barrier as geopolitical accessibility is to oil.
- In terms of accessibility, coal is in an advantageous position over other fossil fuels. There is a tendency for coal to be used by the producers themselves. As a result, domestic transportation is prevalent. Transportation cost barriers, therefore, depend on distances or freight availability.
- Human resource capacity is a major factor that affects energy resource accessibility. There are workforce constraints in many energy industrial sectors, such as trained and technically qualified workers in oil, natural gas, and nuclear sectors and seafarers to man LNG fleets.
- There are several issues that limit accessibility to renewable energy, namely: the lack of financial subsidisation, lack of commitment to promote the use of renewable energy, and limited access to advanced technology.

ENVIRONMENTAL ACCEPTABILITY:

- As for coal, the main barrier is its environmental sustainability. The risk of global climate change from GHG emissions, which have been linked to the use of fossil fuels, in particular coal, is now growing and generating enormous public interest. Carbon capture and storage (CCS) technology is considered a promising technology for drastically reducing CO_2 emissions, if applied. However, there is still a long way to go for this option to be accepted. Therefore, further technology development and commercialisation is one solution to solve the acceptability issue of coal.
- Nuclear power has established itself as a potential energy supply option in some APEC member economies. Its advantages over competing fuels, in terms of environmental aspects (lack of pollutants and GHG emissions) give nuclear energy a competitive edge. However, in the process chain, nuclear does cause some negative environmental impacts, such as toxic contamination to land and water resources and radioactive hazards during the mining process.
- While admittedly a viable and attractive fuel (particularly in transportation sector), Biofuels will cause diverse unintended negative environmental impacts during production.

INVESTMENT COST AFFORDABILITY:

- Besides geopolitical issues and imbalances between demand and supply that result in potential supply disruptions, investment in oil and gas upstream exploration and development is also a concern for supply security. To manage investment bottlenecks, cooperation between IOCs and NOCs is key.
- Despite the recent trend of rising natural gas prices, costs related to LNG infrastructure have been declining. Additionally, LNG tanker construction costs have also decreased in the past decade. An increase in the number of LNG takers is expected, as such increasing total fleet capacity in the future.
- Coal prices have been relatively stable. Among energy resources, coal requires the least investment cost. However, to achieve an economic and environmental balance, coal use is subject to additional costs. For example, the application of CCS technology to reduce CO_2 emission will incur additional costs.
- Nuclear power plants have higher capital costs because it is necessary to use special materials, sophisticated safety features, and back-up control equipment for safety reasons. In addition, prolonged construction periods and regulatory process delays have resulted in additional costs.
- Cost competitiveness is a major challenge for renewable energy. Renewable energy costs more than fossil fuels in terms of specific construction and generation costs. Nevertheless, if external costs are taken into account, renewable energy development will prove beneficial. Technology advancement is considered an effective way to help reduce the cost of renewable energy development.

ENERGY SECURITY INDICATORS

DIVERSIFICATION OF ENERGY SUPPLY SOURCES: ESI_{I}

- Among APEC member economies, Canada, Chile and New Zealand are projected to decrease in diversification.

NET ENERGY IMPORT DEPENDENCY: ESI_{II}

- As a result of low levels of diversification (lack of indigenous resources), Singapore, Hong Kong, Chinese Taipei, Korea, Japan, and Chile show high levels of import dependency.

NON-CARBON BASED FUEL PORTFOLIO: ESI_{III}

- The growth of non-carbon based fuel remains constant in most economies. This is because non-carbon based fuel sources are not growing at a fast enough rate to offset future demand growth.

NET OIL IMPORT DEPENDENCY AND MIDDLE EAST OIL IMPORT DEPENDENCY: ESI_{IV} & ESI_{V}

- ESI_{IV} projected that ten APEC member economies -Australia, United States, Chile, China, Indonesia, Malaysia, Peru, Thailand and Viet Nam- will increase their net oil import dependence by 2030.

- As of 2004, seven APEC economies – Chinese Taipei, Japan, Korea, Malaysia, the Philippines, Singapore, and Thailand- relied over 50% on the Middle East to supply their imported oil requirements. In the future, this trend is expected to increase substantially, as economies increase their oil import dependencies.

CASE STUDY: OIL SUPPLY SECURITY

- The results of this analysis show that oil supply security changes as a result of shifts in the sectoral contributions of demand, economic development, and fuel diversification.
- Oil supply security is most dependent on the degree of fuel diversification within oil intensive sectors and import supply diversification.

POLICIES & MEASURES TAKEN IN APEC TO ENHANCE ENERGY SECURITY

- Within the APEC region as a whole, resource diversification, resource development and transport, and resource trading are the policies that are primarily implemented.
- Technology advancement, such as advanced nuclear energy, clean coal technology, and renewable energy, is also actively pursued in this region. Technology development and innovation will make a difference in addressing the 4A's of energy supply security in the future.

INTRODUCTION

OVERVIEW

Concern over energy security is undoubtedly an important issue for energy policy makers. Since the first oil crisis in the 1970s, energy security has focused primarily on concerns about oil disruption in oil-producing economies, with particular focus on the Middle East. Since then, there has been an energy security paradigm shift. Concerns are not only restricted to oil, all conventional energies are considered.

From 2002-2030, energy demand in the APEC region is projected to increase nearly three-fold, growing at an annual rate of 2.1% to reach 6,759 Mtoe.[a] Concurrently, the region's indigenous resource supply is expected to decrease, resulting in an increase in net import dependence from 36% in 2002 to 52% in 2030.[a] Even though alternative indigenous energy resources - wind, solar, and biofuels- have been used to substitute or replace fossil fuels in certain sectors, widespread use is still plagued by concerns over cost and reliability of resource supply.

[a] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

Currently, the world's combined fossil fuel reserve-to-production ratio estimates less than 200 years of fossil fuel supply. Specifically, oil, natural gas, and coal are about 40, 65, and 164 years respectively. As such, long-term energy supply security, in terms of the availability and accessibility of resources at affordable prices, is becoming of greater concern. In addition, the dwindling of energy resources in the region – as some net energy exporting economies will become net energy importing economies (Malaysia and Indonesia) – has also raised concern.

This capacity shortage, which will be met by imports, will also result in additional energy infrastructure requirements. In 2030, the projected energy infrastructure investment requirements for the region (pipeline networks, tankers, refineries, etc.) will be between US$ 5.95 and 7.55 trillion. A number of developing economies -China, the Philippines, Papua New Guinea, Russia, and Viet Nam- will have to invest more than 2% of their GDP towards energy infrastructure development.

Additionally, it is projected that CO_2 emissions from the energy sector will increase from 14,740 Mtoe (2002) to 27,364 Mtoe (2030). Since the energy sector contributes a significant amount to total emissions, tightening environmental regulation will play an important role in the pursuit of a sustainable energy supply.

ENERGY SECURITY DEFINITION

The definition of energy security has changed over time. In the period post 1970s oil shocks, the definition of energy security related to the avoidance of oil supply risk resulting from potential disruptions of crude oil supply from the Middle East. In this century, other factors that affect fuel supply stability and increase energy price have been added to the previous energy security definition. These factors include political conflicts, unexpected natural disasters, concern on terrorism, and energy-related environmental challenges.

This study defines energy security as the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy. Thus, there are several factors that can influence the 'security' of energy supply, such as: (1) the availability of fuel reserves, both domestically and by external suppliers; (2) the ability of an economy to acquire supply to meet projected energy demand; (3) the level of an economy's energy resource diversification and energy supplier diversification; (4) accessibility to fuel resources, in terms of the availability of related energy infrastructure and energy transportation infrastructure; and (5) geopolitical concerns surrounding resource acquisition. In terms of energy demand elasticity, an economy that is able to decouple economic growth with energy use –through energy efficiency and conservation– will have an advantage in terms of its energy security.

Following the above definition, there are 3 fundamental elements of energy security that will be discussed in this study:

(1) PHYSICAL energy security, the availability and accessibility of supply sources;
(2) ECONOMIC energy security, the affordability of resource acquisition and energy infrastructure development; and
(3) ENVIRONMENTAL SUSTAINABILITY, the sustainable development and use of energy resources that "meets the needs of the present without compromising the ability of future generations to meet their own needs". [b]

[b] Brundtland Report (1987). *Sustainable development definition.* http://www.ace.mmu.ac.uk/eae/Sustainability/Older/Brundtland_Report.html.

STRUCTURE OF THE REPORT

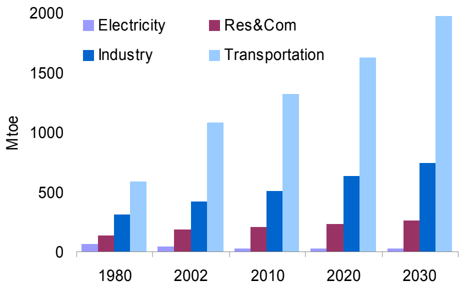
The objective of this study is to provide APEC economies with options for the enhancement of energy security and sustainable development. The study presents a current overview and outlook for energy supply resources, examining the recent projections of respected institutions. In this analysis, an in depth examination of basic constraints that influence economies' ability to attain long-term energy demand –supply balance and possible roles of alternative fuels to alleviate the dependence on fossil fuels and reduce air pollution- is conducted.

To quantity economies' energy supply risk, several energy security indicators are developed. These indicators examine economies' energy resource diversification, in terms of fuel portfolios, political risk of supply acquisitions, and import dependencies. They are designed to provide economies with a relative risk ranking, which can help in determining energy policy priorities. Additionally, several APEC energy policies and measures are analysed to determine their potential applicability to other economies. Implications, based on this analysis, are drawn to facilitate future energy policy planning.

AVAILABILITY

OIL

Oil is the most significant energy source for modern economies, contributing 40% of the world's primary energy demand and 34% of the APEC region's primary energy consumption. Despite oil price shocks and economic depressions, oil consumption in the APEC region has grown by 2.2% a year (1980-2002). Over the next 30 years, oil demand in the APEC region is expected to grow by 1.7% per year [7.1]. Most of this incremental oil demand growth will come from the transportation sector, as transportation systems of developing economies, in particular, become increasingly motorised with few alternative fuels to oil.



7.1 APEC oil consumption by sector 1980-2030

APERC 2007

Thus, this growing dependence on oil, coupled with current high oil prices, declining oil discoveries, and the low level of spare oil-production capacity worldwide, have generated concern about the future adequacy of oil supply. How much oil do we have in the world? Is that enough to meet the ever increasing global demand and if not, what will be the substitute? These questions have become increasingly important since oil is the dominant source of world energy today and will continue to be so for the foreseeable future.

WORLD OIL SUPPLY & RESERVES

In 2005, OPEC accounted for 75% of the world's oil reserves, but only 42% of the world's oil production. In contrast, non-OPEC accounted for only 15% of the world's oil reserves and 43% of total production. In particular, the Former Soviet Union (FSU) accounted for 10% of oil reserves and 15% of total production.

The global oil reserve to production ratio (R/P ratio) increased from 29 years in 1980 to 41 years in 2005. During this period, the non-OPEC R/P ratio declined from 17 years to 14 years. In contrast, the Former Soviet Union's R/P ratio increased dramatically from 19 years to 28 years.

	1980	1990	2000	2005
World Reserves (B. barrels)	**667**	**1,001**	**1,115**	**1,201**
Total OPEC	434.6	765.9	840.5	902.4
Non-OPEC	150.5	171.7	180.8	175.4
FSU	82.0	63.3	93.4	122.9
World Output (mb/d)	**63**	**65**	**75**	**81**
Total OPEC	27	25	31	34
Non-OPEC	24	29	36	35
FSU	12	12	8	12
World R/P ratio (years)	**29**	**41.8**	**40.7**	**40.5**
Total OPEC	43.6	85.1	73.3	73
Non-OPEC	17.4	16	13.9	13.5
FSU	18.5	14.9	31.9	28.4

7.2 World oil reserves and production

British Petroleum (2006). BP Statistical Review of World Energy 2005.

Reserve change is caused by production (downward), new discoveries (upward), and reserve growth (upward).[a] World proven oil reserves, which were 667 billion barrels in 1980, increased to 1,201 billion barrels in 2005. During this period, around 650 billion barrels of oil were produced. Reserve additions, during these 25 years, were estimated at 1,218 billion barrels, with new discoveries and reserve growth accounting for 340 billion barrels and 777 billion barrels respectively.[b]

The world's new oil discoveries peaked from 1956-1965, with about 520 billion barrels detected during those 10 years. Since then, the rate of new discoveries has been declining, averaging at about 10 billion barrels per year for the last 20 years. The decline in oil discoveries has been most dramatic in the Middle East and FSU. In the Middle East, discoveries have been continuously decreasing every decade from 187 billion barrels (1963-1972) to 90 billion barrels (1973-1982), 30 billion barrels (1983-1992), and 16 billion barrels (1993-2002).[c]

[a] Reserve growth is defined as the increase in estimated field sizes, which typically occur as oil and gas fields are developed and produced through processes such as field extensions, new pool discoveries, revisions, and improved recovery.

[b] From IHS energy data base (The amount does not include data from the US and Canada)

[c] International Energy Agency (2004). World Energy Outlook 2004, 97.

The credibility of OPEC official reserves data, however, is under question. From 1981-1990, total OPEC reserve growth was unusually large. During the oil slack period in the middle of the 1980s, Saudi Arabia and Kuwait revised their reserves upwards by about one half. The United Arab Emirates and Iraq also recorded large upward revisions. As a result, total Middle East reserves jumped from 398 billion barrels in 1985 to 663 billion barrels in 1990. This revision was prompted by a discussion among OPEC countries to set production quotas based on reserves.[d] Basically, the revised proven reserves were inflated by applying higher recovery factors (including probable and possible reserves) in order to obtain higher quotas.

[d] International Energy Agency (2005). World Energy Outlook 2005, 125.

In addition, official reserves data in most OPEC countries does not reflect the actual production data. Kuwait, for example, did not change its reserves value of 96.5 billion barrels (from 1991 to 2002) even though the country produced more than 8 billion barrels and did not make any important discoveries during that period.[e]

[e] International Energy Agency (2005). World Energy Outlook 2005, 125.

WORLD OIL RESOURCES ASSESSMENT

	Cumulative Production	Remaining Reserve	Reserve Growth	Undiscovered Resources	Total
Total (B.barrels)	**717**	**959**	**729**	**939**	**3,345**
Crude oil	710	891	674	724	2,999
NGL	7	68	55	215	345

8.1 Ultimate recoverable conventional oil resources

U.S. Geological Survey World Petroleum Assessment 2000

According to the U.S. Geological Survey's (USGS) 2000 resource assessment,[f] the ultimate recoverable oil mean is estimated to be 3,345 billion barrels (including NGL), a 47% increase from the previous estimate of 2,273 billion barrels.[g, h] This projection assumes a future resource additions growth of 674 billion barrels, which is nearly as large as the estimated growth in undiscovered resources (724 billion barrels). It is also important to note that oil resources (excluding NGL) from the existing oil fields (remaining reserves plus reserve growth) account for 52%, undiscovered oil resources account for 24%, and the remaining 24% has already been consumed as of December 1995.

[f] The USGS 2000 assessment analyses the world's conventional oil, gas, and natural gas liquids (NGL) resources. This analysis excludes heavy oil (API gravity <15 degree), tar deposits (oil sands), oil shales, gas hydrates, gas dissolved in geo-pressured brines, and coal bed methane. The U.S. is not covered in this analysis.

[g] The USGS 2000 assessment is based on production and reserves data from January 1, 1996. It covers potential resource additions from 1996 to 2025.

[h] The USGS also presented a 95% probable estimate of 2,248 billion barrels and a 5% probable estimate of 3,896 billion barrels.

The areas that contain the greatest volume of undiscovered conventional oil are the Middle East, the West Siberian and Caspian areas of the Former Soviet Union, and the Niger and Congo delta areas of Africa. New, undiscovered oil resource potential was also identified in a number of areas with no significant production history, such as Northeast Greenland (50 billion barrels) and offshore Suriname (15 billion barrels).[i]

[i] Many frontier geologic provinces world wide remain to be assessed. NE Greenland is a typical province even though geologic, engineering, economic and environmental uncertainty are significant and operational cost is expensive. (*USGS Ongoing Assessment of Undiscovered Petroleum Resources of the World (2006).* HIS 2006 energy User Forum.

In interpreting these values, it must be acknowledged that petroleum resource assessments include a broad range of uncertainties, despite the use of the best available knowledge. As such, these assessments evolve to reflect knowledge, technology, and economic changes over time.

For example, there is concern that the USGS 2000 assessment might overestimate reserves, since reserve growth for the OPEC region might already be included in the remaining reserves estimate to some degree (in the order of several hundred billion barrels). If this is the case, there are two problems concerning the reserves and resources estimates. First, inflated reserves in OPEC are not readily available for production because they are subject to future recovery enhancement through advanced EOR or intensive infill drilling. Second, inflated reserves are double counted in the category of remaining reserves and future reserve growth, making the USGS assessment inflated by that amount. For that reason, these issues have been recognised by the USGS and are under review for future assessments.

Nevertheless, even with these overestimates, the USGS' assessments are still considered the most reliable at present and are referred to in most energy outlook studies, including the *World Energy Outlook (WEO)* by the IEA and the *Annual Energy Outlook (AEO)* by the EIA.

PEAK OIL DEBATE

Since the mid-nineteenth century, there have been concerns over the imminent peak and the following decline of oil production. In the last few years, this issue has resurfaced and will continue to be a "hot topic" on the international stage. According to Dr. G.C. Watkins, an energy policy expert, there are two different views on the oil reserves depletion debate.

Pessimistic view – The pessimistic view, which is based on Dr. M. King Hubbert's methodologies, predicts an imminent oil production peak in the foreseeable future.[j]

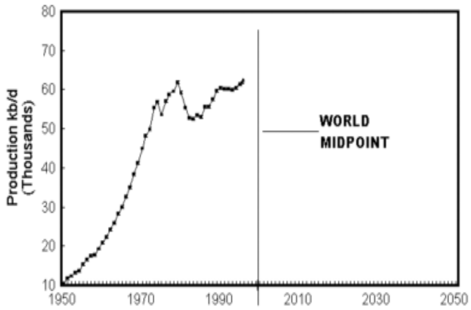
Figure [9.1] shows the world oil production profile to date, with cumulative production being at 990 billion barrels (2005). If ultimate recoverable oil resources are estimated to be 1,980 billion barrels, the oil peak has already arrived.[k] Several pessimists have projected that the peak of world oil production will be reached by 2010, at the latest, while optimistic assumptions suggest it is most likely after 2020.

Optimistic view – The optimistic view claims that market mechanisms and technology will determine when oil production will peak. As shown in [9.2], a supply function moves up from S to S_1 in response to new discoveries and cost-effective technological improvements; as resource depletion continues, supply shifts downwards to S_2. According to followers of this theory, analysis on "whether an aggregate crude oil supply function is shifting, and if so in what direction, is at the crux of any assessment of the oil industry outlook." [l]

The fundamental difference, between these two views, is on the ultimate conventional oil resource estimate. Optimists believe physical (geological) limits have not been reached and that resources increase along with demand.

The critical factors that affect the timing of peak oil are the amount of new discoveries, reserve growth, and the accuracy of remaining reserve estimates. Many scenarios have been developed to determine the world oil production peak. EIA's energy outlook, which is based on the USGS estimates, shows that oil peak will arrive around 2030. Similarly, another EIA study, showed that world conventional

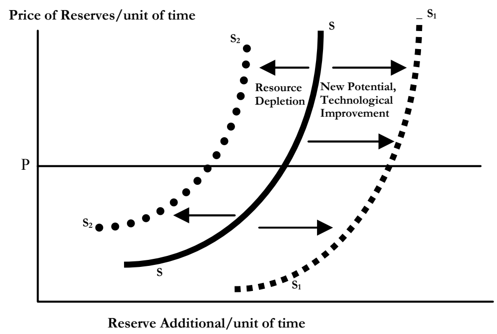
[j] Dr. M. King Hubbert, a geophysicist, is well known as a world authority on the estimation of energy resources and on the prediction of their patterns of discovery and depletion. In 1956, Dr. Hubbert demonstrated that symmetric bell shaped logistical curves fit the production profiles (Production growth, production peak, and production decline stages) of oil fields. In logistic curves, a peak is reached when half of the ultimate resources are produced.



9.1 The life time of natural resource, pessimist

The Hubbert Peak of World Oil 2003

[k] The ultimate recoverable resources estimate (1995) made by Campbell & Laherrere, who are the representative oil peak alarmists and the authors of "The End of Cheap Oil (1998)" , stands at 1.8 trillion (1,800 billion barrels) .



9.2 Oil supply curves, optimist

G.C. Watkins 2006

[l] G.C. Watkins (2006). *Oil scarcity: What have the past three decades revealed?* Energy Policy 34, 508-514.

crude oil production could peak in 2037, at a production of 53.2 billion barrels a year (mean estimate).[m]

LONG TERM OIL SUPPLY & RESERVES

The oil supply outlook, shown in [**10.1**], was projected by the IEA, EIA and OPEC. As seen from the projections, the future world oil incremental demand will be met by OPEC supply, which will increase substantially to 40-45% from 2010 to 2020. In contrast, non-OPEC supply is projected to decline from 56% to 47% (IEA 2005 case) or 62% to 54% (OPEC 2005 case). Despite the fact that proven reserves increased recently in the FSU, its share of supply to the market is estimated to be flat during the projection period, around 14-15% from 2010 to 2020.

Another projection suggests that oil production is 990 billion barrels, remaining reserve is 1,200 billion barrels, and future additions (reserve growth and undiscovered resources) will be 1,154 billion barrels. [n,o] With an annual production of 81.1 million bpd in 2005, the R/P ratio is calculated at 41 years, and the "depletion year" is in 80 years.[p]

	2002	2004	2010	2020
IEA (05)	**-**	**82.1**	**92.5**	**104.9**
Non-OPEC	-	46.7	51.4	49.4
FSU	-	11.4	14.5	15.6
OPEC	-	32.3	36.9	47.4
EIA (05)	**80.0**	**-**	**96.5**	**113.6**
Non-OPEC	49.4	-	56.6	63.9
FSU	11.4	-	13.9	16.9
OPEC	30.6	-	39.9	49.7
OPEC (04)	**77**	**-**	**88.7**	**105.6**
Non-OPEC	47.8	-	54.6	56.7
FSU	9.5	-	13.5	15.3
OPEC	29.2	-	34.1	48.9

10.1 Comparison of oil supply projections (mbd)

Robert Skinner, Phd. (2006). World Energy Trends: Recent Developments and their Implications for Arab Countries, Oxford Institute for Energy Studies. May 2006.

SUPPLY FROM NON-OPEC

Non-OPEC supply can be broken down as follows:

MATURE BASINS

Mature basins include the North Sea, onshore US, Alaska, conventional oil in Canada, Mexico, Egypt, China and so forth; namely, those areas where there are believed to have some prospect of a reversal of production decline. These basins are projected to decline in production from 2 to 1.7 % in the next ten years.[q]

RUSSIA

Russian oil production reached its peak in 1987 at about 11.4 Mb/d. In 1996, the production fell to 6 Mb/d, partly as a result of the collapse of the Soviet Union. Russia is the most important non-OPEC oil producer, however, production has slowed since early 2005 and it is projected that Russia's oil production will not exceed 11.5 Mb/d by 2020.

CASPIAN REGION

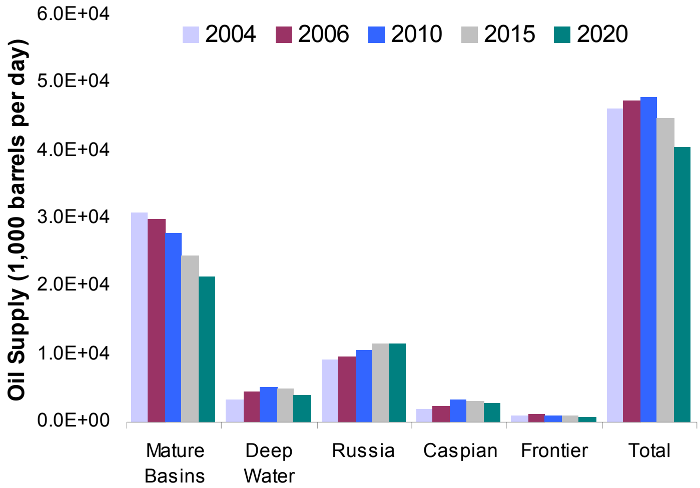
By 2010, production from this area is estimated to range from 2.9 Mb/d to 4 Mb/d. According to EIA projections, the Caspian region could supply an additional 1.5 Mb/d by 2010.

[n] U.S. Geological Survey World Petroleum Assessment 2000 and British Petroleum (2006) BP Statistical Review of World Energy 2005.

[o] USGS 2000 assessment does not include oil sands for production and reserves.

[p] David L. Greene, Janet L. Hopson and Jia Li (2006). *Have we run out of oil yet? Oil peaking analysis from an optimist's perspective.* Energy Policy 34, 515-531.

[q] Robert Skinner, PhD. (2006). *World Energy Trends: Recent Developments and their Implications for Arab Countries*, Oxford Institute for Energy Studies.



11.1 Oil supply from non-OPEC

Robert Skinner, PhD. (2006). World Energy Trends: Recent Developments and their Implications for Arab Countries, Oxford Institute for Energy Studie..

DEEP WATER

Deep water fields consist of the US Gulf of Mexico, offshore Brazil, and the Gulf of Guinea in West Africa. Production in these areas could account for up to 50 billion barrels of recoverable oil, with half of this coming from the Gulf of Mexico. Currently, approximately 6 billion barrels are being produced.

NON-CONVENTIONAL RESOURCES

Beyond 2030, the future of oil will have to include the production of significant volumes of non-conventional resources, such as synthetic fuels and unconventional oil.

NON-CONVENTIONAL OIL is costly and reserves appear to be highly concentrated in a few places. Nevertheless, it is expected to become an alternative source of energy to replace conventional oil.[r] Options include:

Oil sands - *a mixture of clay, sand, water and bitumen:* Canada has huge deposits of oil sands. The total proven reserve is estimated to be about 174 billion barrels, making Canada second only to Saudi Arabia in terms of oil reserves.[s] Recently, more resources have been reported from Brazil, China, Russia, India, Madagascar, the United States, and Zaire. According to the EIA's IEO 2006 projection, oil sands production will reach 3.5 Mb/d in 2030, up from 1.0 Mb/d in 2005.

Oil shale - *a sedimentary rock that contains a solid hydrocarbon-like substance:* Because of the large resource volume, oil shale is considered a "backstop" for conventional petroleum production. Worldwide estimates of the oil shale resource are projected at approximately 255.9 Gtoe; the US, at around 154.8 Gtoe, has most of the world's shale oil.[t]

So far, oil recovery from oil shale has not proved to be commercial. Currently, the US and major oil companies are investing in pilot projects. The US Energy Department forecasts a production rate of two million barrels a day by 2020 and ultimately 10 Mb/d.[u]

Orinoco oil belt - *the ultra-heavy crude oil deposits in Venezuela:* Development and production started more than 15-20 years ago. Today, several major oil companies have declared their interest to develop new greenfield projects and some projects are

[r] The term of conventional and non-conventional petroleum resources is based on density and viscosity, as well as the presence of contaminants. Non-conventional fuel occupies the heavy low grade and is difficult-to-extract and refine.

[s] Alberta Department of Energy 2004.

[t] David L. Greene, Janet L. Hopson and Jia Li (2006). *Have we run out of oil yet? Oil peaking analysis from an optimist's perspective.* Energy Policy 34 , 515-531.

[u] Energy Bulletin 2006.

already under construction. This will increase total production capacity from 0.4 Mb/d in 2002 to about 1 Mb/d in 2010. By 2030, EIA projects that 1.7 Mb/d of worldwide production will be achieved.

The Canadian tar sands and the Orinoco oil belt have about 4,000 billion barrels of oil in place; however, only 15% could be extracted with today's technology.[v]

[v] Peter R. Odell (2004). *Oil's Long Term Future; 85% yet to be explored.* Paper Presented to the Energy Institute Conference, "Oil Depletion: No Problem or Crisis?", 10 November 2004, London, United Kingdom.

UNCONVENTIONAL LIQUIDS are engineered sources that have been considered for a long time, but have not yet been economic for wide use. Options include the following resource transformations:

Biomass to Liquids – *Ethanol and Bio-diesel:* Biofuels are becoming more important, particularly as a substitute for oil in the transport sector. Currently, ethanol accounts for most of the biofuel used. Production is mainly located in Brazil and the United States, whose combined production accounted for more than 90% of total world ethanol supplies in 2005.

With the intent of securing future energy supply, several governments have recently announced pro-biofuel policies and set targets for future production. These economies include Australia, Canada, China, Malaysia, New Zealand, the Philippines, Thailand, and the US. Even though supplies have to be imported, Japan also has adopted a clear policy for biofuels blending. EIA has projected that by the year 2030 worldwide biofuels production will increase from 0.7 Mb/d in 2005 to 2.1 Mb/d.

Coal to Liquids (CTL): For decades, scientists have known how to convert coal into a liquid that can be refined into gasoline and diesel fuels, but the process was considered too expensive to be practical.

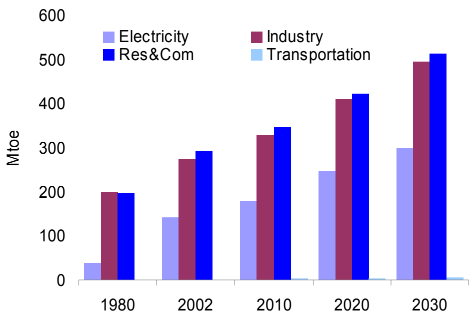
The exception was in South Africa. With limited access to foreign oil, Sasol Ltd, a partly state-owned South African company emerged as a key player in coal-to-liquid technology, with the capacity to produce 160,000 barrels of oil a day. China is now building a coal-to-oil plant in Inner Mongolia and may add as many as 27 facilities (including some with Sasol's help) that are expected to produce 1 Mb/d by the middle of the next decade.

In the US, the Defence Department is now studying coal-to-oil technology as a way to reduce the military's dependence on Middle Eastern crude oil. In addition, the National Coal Council, an industry association, is pushing for government incentives to help generate, by 2025, 2.6 million barrels per day of liquid fuel from coal. The plan would require 475 million tons of coal a year, which is 40% more than the current annual production in the US.

Gas to Liquids (GTL): Recently, there have been many project proposals, with a total capacity of 2 Mb/d. The Royal Dutch Shell Group, currently, is operating specialised GTL plants in Egypt (3.8 million tonnes per year), Trinidad & Tobago, and Malaysia.

In general, the GTL process has been considered largely economical when the price of crude oil is over US$35 per barrel. Consequently, GTL output is expected to account for 165 Kb/d by 2010, increasing –primarily from Qatar- to 800 Kb/d by the middle of the next decade.

Traditionally, heavy dependence on Middle Eastern oil and rising oil prices have been the principal drivers for economies to diversify their fuel sources. In recent years, many economies have switched their electricity generation from fuel oil to natural gas since it produces less carbon emissions than other fossil fuels. Additionally, natural gas allows power plants to operate at higher efficiency levels. Through the adoption of highly efficient generation technologies, such as combined cycle technology, plants can increase generation efficiencies from the 35-45% range to the 45-55% range.



13.1 APEC Natural Gas Consumption by Sector, 1980-2030

APERC 2006

In the APEC region, natural gas demand, from 2002-2030, is projected to increase at an average of 2.4% per year; while coal and oil are expected to increase at 2.8% and 1.7% respectively.

The two largest sectors of natural gas consumption in the APEC region are the electricity generation and industry sectors. From 2002 to 2030, the electricity sector is projected to remain the leading sector for natural gas demand, accounting for 42% to total natural gas demand growth.[w]

[w] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

NATURAL GAS RESERVES AND RESOURCES

According to BP's *Statistical Review of World Energy 2006*, there are significant natural gas reserves in the world [13.2]. At the end of 2005, world gas reserves were about 180 Tcm. The three largest proprietors of gas reserves in the world -Russia, Iran, and Qatar- have 50% of the world's natural gas reserves. Central and South America, Europe and Eurasia, Africa, and the Middle east have a reserves to production ratio of 52 years, 60 years, 88 years, and more than 100 years respectively.

	Tcm	Share of Total world %	R/P ratio year
Australia	2.52	1.4	67.9
Brunei Darussalam	0.34	0.2	28.3
Canada	1.59	0.9	8.6
China	2.35	1.3	47.0
Indonesia	2.76	1.5	36.3
Malaysia	2.48	1.4	41.4
Mexico	0.41	0.2	10.4
Papua New guinea	0.43	0.2	*
Peru	0.33	0.2	*
Russia	47.82	26.6	80.0
Thailand	0.35	0.2	16.5
USA	5.45	3.0	10.4
Viet Nam	0.24	0.1	45.6
Total APEC	**67.07**	**37**	
Total S. & Cent. America	7.02	3.9	51.8
Total Europe & Eurasia	64.51	35.6	60.3
Total Middle East	72.13	40.1	*
Total Africa	14.39	8.0	88.3
Total World	**179.83**	**100**	**65.1**

13.2 Proven natural gas reserves, 2005

British Petroleum (2006). BP Statistical Review of World Energy 2005.

** More than 100 years*

In the APEC region, proven natural gas reserves were recorded at 67 Tcm in 2005. That accounted for 37% of the world's total proven reserves. Among APEC economies, Russia holds the biggest natural gas reserves in the region, accounting for 71% of total APEC reserves. Russia's reserves-to-production ratio is around 80 years. The US, Indonesia, Australia and Malaysia also have significant reserves. Nevertheless, the APEC region's natural gas reserves are still less than the gas reserves in the Middle East, which account for 40% of the world's proven reserves.

According to the USGS's 2000 assessment, the world's ultimate mean (most probable) of recoverable natural gas resources are 15,401 trillion standard cubic feet (Tcf), which is equivalent to 2,567 billion barrels of oil.[x] From the previous assessment, natural gas resource estimates increased by 34%. Reserve growth (3,660 Tcf) accounts for 41% of this increase in resources.

[x] Six thousand cubic feet of gas equals one barrel of oil equivalent.

	Cumulative production	Remaining Reserves	Reserve Growth	Undiscovered Resources	Total
Total (Tcf)	1,752	4,739	3,660	5,196	15,401

14.1 Ultimate recoverable natural gas

U.S. Geological Survey World Petroleum Assessment 2000.

The percentage of undiscovered gas resources (5,196 Tcf) against ultimate recoverable is 34%, which is larger than the one for oil (24%). This implies that there are more exploration lags for gas than oil. Areas that contain the greatest volumes of undiscovered conventional gas include the West Siberian Basin, Barents and Kara Sea shelves, the Middle East, and the Norwegian Sea.[y] Areas that may contain significant additional undiscovered resources, where large discoveries have been made but remain undeveloped, include East Siberia and the Northwest Shelf of Australia.

[y] U.S. Geological Survey World Petroleum Assessment 2000.

NATURAL GAS SUPPLY

According to EIA projections for 2003-2030, Russia and the US are the biggest suppliers of natural gas globally, accounting for almost three-quarters of the total supply in 2003, at 22 trillion cubic feet and 19 trillion cubic feet respectively.[z] The growth in natural gas production in Africa is mainly for export via pipeline and LNG. In Asia, all of the production growth will go towards meeting domestic consumption.

LIQUEFIED NATURAL GAS

Liquefied Natural Gas (LNG) is expected to be an important source of natural gas supply as a result of declining domestic resources. Table [14.2] shows a doubling in LNG trade from 1995 to 2005, from 8 producers trading 3,289.77 Bcf to 13 LNG-producers trading 6,827.5 Bcf of LNG.[aa] Trade numbers are expected to increase. According to the EIA International Outlook 2006, Russia is expected to become a LNG exporter in 2008 when the Sakhalin liquefaction project begins operation. Also, in South America, Peru is scheduled to have its first liquefaction terminal in 2009.

Globally, LNG exports are projected to increase from 130 Mt in 2004 to 368 Mt in 2010.[ab] In the APEC region, demand for LNG is expected to double during 2005-2015. Japan and Korea will remain the largest markets, while a strong demand is expected to grow in Chile, Chinese Taipei, and the US.

	Year					
	03	10	15	20	25	30
OECD	**39**	**40**	**42**	**44**	**50**	**45**
United States	19.0	18.6	20.4	21.6	21.4	21.2
Canada	6.5	6.1	5.8	5.5	5.8	6.2
Mexico	1.5	1.7	1.9	2.2	2.6	3.0
Europe	10.7	10.9	11.0	10.7	10.7	10.3
Australia/ New Zealand	1.4	2.3	3.1	3.8	4.2	4.6
Japan	0.1	0.1	0.1	0.1	0.1	0.1
Non-OECD	**60**	**76**	**92**	**105**	**120**	**136**
Russia	21.8	26.8	30.4	33.5	36.6	41.5
Other Eurasia	6.1	7.1	7.8	8.5	9.0	9.6
China	1.2	2.4	3.0	3.5	3.9	4.4
India	1.0	1.1	1.3	1.6	1.9	2.4
Other Asia	7.5	9.3	12.2	14.8	17.8	20.6
Middle East	9.1	14.2	17.1	19.8	23.1	26.2
Africa	5.1	8.7	11.4	14.3	16.3	18.5
Central & South America	4.2	6.7	8.4	9.6	11.4	13.0
Total World	**95**	**116**	**134**	**149**	**165**	**182**

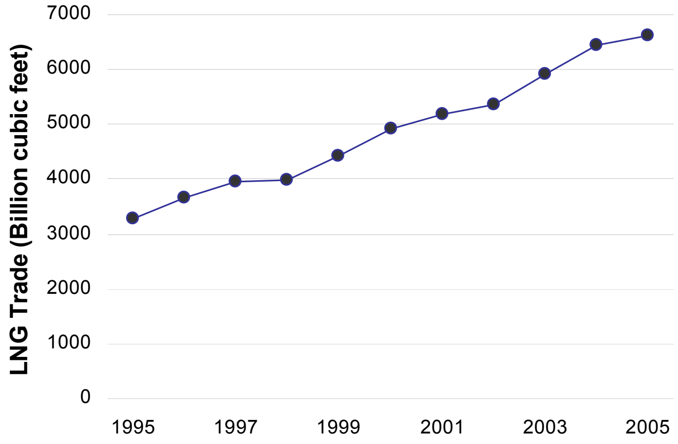
14.2 World natural gas production, 2003-2030 (trillion cubic feet)

Energy Information Administration (2006). International Energy Outlook 2006. USA.

[z] EIA projections for 2003-2030.

[aa] Algeria, the United States, Libya, Brunei Darussalam, United Arab Emirates, Indonesia, Malaysia, Australia, Qatar, Nigeria, Trinidad & Tobago, Oman and Egypt.

[ab] Gary Walker (2007). *Australia's LNG Industry*, paper presented to APERC Annual Conference 2007.



15.1 World LNG Trade, 1995-2005 (billion cubic feet)

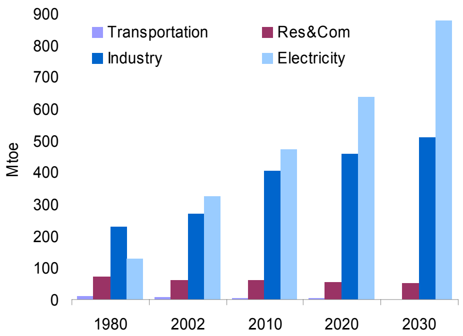
Energy Information Administration (2006). International Energy Outlook 2006. USA.

COAL

In recent years, coal has made a comeback due to its availability, relatively even spread of resources, price advantages over other fossil fuels, and the emergence of both promising and proven technologies that may tackle the environmental problems associated with coal use. In terms of prices, coal is considered to have an advantage over other fossil fuels, since coal prices are lower, more stable, and not susceptible to geopolitical price fluctuations.

It is projected that the average annual growth rate for coal will grow at 2.8%, from 2002 to 2030, to reach 3,366 Mtoe in 2030, approximately 33% of the total primary energy demand in that year. Most of the coal in the APEC region, about 81%, will be consumed by electricity and heat generation. Through 2030, coal will account for 46%, or about 959 GW, of the total capacity addition in the electricity generation sector [15.2].

Projections show that coal consumption will reach 560.162 Mtoe in 2030, a 66% increase from the total final coal demand in 2002. [ac] From 2002-2010, coal demand is projected to grow 4.2% annually, with China accounting for 80% of the region's coal demand growth. After 2010, however, the growth rate will slow down to 1.0% per year (2010-2020) and then further reduce to 0.8% per year (2020-2030). The rapid demand growth from 2002-2010 is attributed to a robust growth in coal demand (5.1% per year) for the industry sector, which will increase almost 50% from the 2002 value of 271.2 Mtoe. In addition, China's rapid economic development, contributing to an annual GDP growth of 7.7% from 2002 to 2010, will initiate an increase in coal use for the electricity generation and industry sectors.



15.2 APEC Coal Consumption by Sector 1980-2030

APERC 2006

[ac] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

COAL RESERVES AND RESOURCES

As of the end of 2005, total world coal recoverable reserves are estimated at 909,064 million tonnes, which is enough supply for more than 100 years at current consumption levels [16.1].

The APEC region has roughly 62%, or 911,924 million tonnes, of the world's total coal reserves. These reserves are widely distributed in three economies: the US (27%), Russia (17%), and China (13%). The United States, Russia, China, and Australia account for 98%, about 596,653 million tonnes, of the region's total proven coal reserves; China and Australia have R/P ratios of about 250 years and Russia has an R/P ratio of more than 500 years.[ad]

Because of the abundant reserves, the region will have enough coal supply to cover its demand through to 2025. In addition, the region will remain a net coal exporter until 2025; however, it will become a marginal coal importer in 2030 (at an export to import ratio of 0.1%).

However, coal-to-liquid (CTL) technology is becoming increasingly attractive, as economies are trying to find alternatives for oil in the transport sector. The development of coal-to-liquid technology may further increase the demand for coal. Approximately 2-4 billion tonnes of coal are required for 70,000-80,000 b/d CTL plant capacity.[ae] Only time will tell the impact that widespread CTL technology applications will have on the depletion rate of the coal reserves.

	Total (M. tonnes)	R/P Ratio (Years)	Share to world total (%)
Australia	78,500	215	8.64
Canada	6,578	100	0.72
China	114,500	59	12.60
Indonesia	4,968	38	0.55
Japan	359	268	0.04
South Korea	80	25	0.01
Mexico	1,211	135	0.13
New Zealand	571	115	0.06
Russia	157,010	>500	17.27
Thailand	1,354	67	0.15
USA	246,643	245	27.13
Viet Nam	150	6	0.02
APEC Total	**611,924**	**158**	**67.31**

16.1 Proven Coal Reserves, 2005

British Petroleum (2006). BP Statistical Review of World Energy 2005.

[ad] The world's average coal R/P ratio is 164 years.

[ae] Sprott Asset Management.

NUCLEAR

There are 442 nuclear power plants, with a generating capacity of 370 GW, operating in 30 countries worldwide.[af] Currently, nuclear energy supplies 16% of the world's base-load electricity supply. According to the International Atomic Energy Agency (IAEA), electricity generated by nuclear energy will increase from 368 GW in 2005 to 423-640 GW in 2030. Long-term energy security and environmental sustainability are major drivers for this growth in nuclear power plants. Nuclear energy is widely considered as an effective option to help reduce pollutant emissions, such as SO_2, CO_2, and NO_X, in the power sector.

In the APEC region, there are 240 nuclear power plants in operation with a capacity of 205 GW. There are a number of nuclear development projects in the region:

Australia: Australia, which has about 40% of the world's uranium reserves, does not currently have any commercial nuclear power plants, however, it has started to consider nuclear energy. In June 2006, the government commission recommended the construction of 25 nuclear reactors by 2050.[ag]

China: China has 10 nuclear power plants in operation, 30 plants under construction, and is planning to construct more than 18 plants by 2020.

[af] Sueo Machi (2007). *Nuclear Energy for Sustainable Development*, paper presented at APERC Annual Conference 2007.

[ag] International Herald Tribune , 23 November 2006.

Indonesia and Viet Nam: These two economies are planning to have nuclear power plants in operation by 2018 and 2020 respectively.[ah]

[ah] Sueo Machi (2007). *Nuclear Energy for Sustainable Development*, paper presented at APERC Annual Conference 2007.

Japan: There are two nuclear power plants under construction and 11 plants are under development.

Korea: There are four nuclear power plants under construction and another four are under development.

US: There are 103 nuclear power plants in operation; no new construction has been added since the Three Mile Island accident in 1979.

In terms of the APEC region's nuclear electricity demand, it is expected to grow at 1.9% per year, from 1,488 TWh in 2002 to 2,526 TWh in 2030. Nevertheless, nuclear energy's share to total primary energy demand is projected to remain stable at 6% between 2002 and 2030. Over the outlook period, China is expected to exhibit the highest growth, increasing at 10.5% per year. In South East Asia, Viet Nam seems to be the first economy to use nuclear power.[ai]

[ai] APERC (2006). *APEC Energy Demand and Supply Outlook 2006: Economy Review.*

FUEL RESOURCES

Uranium, which is relatively abundant and found in many locations around the world, is a common nuclear fuel source. Among APEC economies, Australia, Canada, Russia and the US are producers. World uranium reserves are estimated at 2.3 million tonnes. These reserves are sufficient to meet the demand of existing and planned nuclear power plants well into the 21st century. Assessments of total conventional uranium reserves and resources estimate that there are about 20 million tonnes.[aj]

[aj] Hans-Holger Rogner. *Energy Resources.*

ACCESSIBILITY

Besides the availability of energy resources, the ability to access these resources is one of the major challenges to securing energy supply to meet future demand growth. Barriers to energy supply accessibility, such as economic factors, political factors, and technology are described in this section.

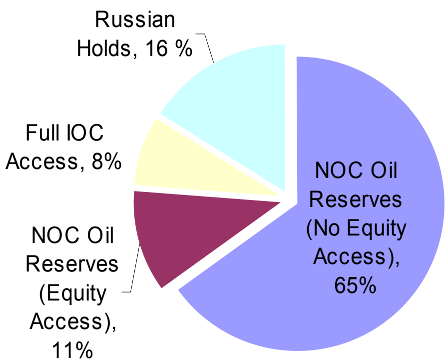
OIL

Barriers to oil resource accessibility include:

GEOPOLITICAL FACTORS

As previously mentioned, global oil resources are unevenly distributed; most of these resources are concentrated in the Middle East (about 75% of current proven reserves), Africa, North and South America, and Russia.

International oil companies (IOCs) face difficulties in gaining access to proven reserves or new resources in politically unstable regions. Presently, IOCs control less than 20% of proven oil reserves worldwide. As shown in Figure [19.1], IOCs have full access to 8% of the world's proven oil reserves and 11% equity access to National Oil Companies (NOCs), whereas NOCs (excluding Russia) hold about 65%.



19.1 Proven Oil Reserves Controlled by IOCs vs. NOCs, 2006
D.Sedney 2006

Currently, there is a growing debate over the oil development effectiveness of NOCs and IOCs. In terms of investment purpose, NOCs generally have different objectives than IOCs. IOC's investments are based on returns and profit margins, while NOCs may have other agendas, such as economic independence, social benefits, and both the economic and environmental sustainability of their reserves. The basic argument is that NOCs might lack sufficient capital or technology to sustainably develop their oil resources. "Whilst IOCs need access to new reserves, NOCs need access to the expertise of IOCs to develop the business".[a] As such, cooperation between NOCs and IOCs can benefit both parties by enhancing the accessibility, (through technology transfer) of new supply reserves, which can increase overall profits.

[a] Scaroni, Petroleum Intelligence Weekly. Vol. XLV, No.50, December 11, 2006.

GEOGRAPHICAL CONSTRAINTS

Another barrier is related to geography, since large amounts of undiscovered resources are in very deep sea or arctic areas. Therefore, oil companies face difficulties in reaching them because of high development costs and environmental restrictions.

Most of the undiscovered oil in North America is expected to be found in the US (83 billion barrels) [b]; its main portion is located in the deep waters of the Gulf of Mexico. In terms of the undiscovered oil in Europe (50 billion barrels), Greenland will contribute significantly to this resource supply.

[b] Assessment does not include Canadian oil sands (USGS 2000)

New conventional liquid additions, from 1996 to 2005, are low for North America, Europe, the Former Soviet Union, and the Middle East. For the first two regions, exploration activities are limited to mature fields; the amount of discoveries is very small relative to the size of total projected undiscovered resources (geographical barrier). For the latter two regions, exploration activities are projected to be very low, in comparison to the expected resources, because of limited NOC/IOC cooperation (geopolitical barrier). As for the Middle East, in particular, national oil companies are not compelled to drill exploratory wells because they already have sufficient, profitable reserves.

In Africa and the Asia Pacific, however, significant new discoveries are projected. This is attributed to an increase in exploration activities, which imply that there are minimal barriers to resource accessibility in these regions.

WORKFORCE CONSTRAINTS

The oil and gas industry is facing a shortage of trained and technically qualified workers. Overall, since 1986, the global oil and gas industry workforce has decreased by 39%, from 2.8 million to 1.7 million.[c] According to a survey conducted in 2004 by the American Petroleum Institute (API),[d] for the United States petroleum industry, there will be a shortage of engineers and geoscientists (38%) and instrumentation and electrical workers (28%). Additionally, a study done in 1999 by the United States' National Petroleum Council[e] projected that over the next decade there will be a personnel shortage of approximately 40% as a result of workforce retirements.[f] The study specifically stated that "aggressive pro-active workforce planning is essential" and that "without immediate action, impending shortages of qualified personnel are expected to hinder the ability of the producing sector to find and develop required gas supplies".[g] These conclusions are aligned with the major consensus that the workforce of the oil and gas industry is declining, and action must be taken to reverse this trend.

[c] James Thomas. (2003). *How the Oil and Gas industry will identify, recruit, and manage its human resources over the next decade.* Business Briefing: Exploration and production.

[d] The American Petroleum Institute (API) is a national trade association that represents all aspects of America's oil and natural gas industry.

[e] The National Petroleum Council is an oil and natural gas advisory committee to the Secretary of Energy for the USA.

[f] Deloitte Research Institute (2005). *The Talent Crisis in Upstream Oil and Gas: Strategies to Attract and Engage Generation Y.*

[g] National Petroleum Council (1999). *Natural Gas: Meeting the challenges of the nation's growing natural gas demand.*

TECHNOLOGY CONSTRAINTS

In the future, oil demand will have to be met by non-conventional oil, such as oil sands from Canada and the oil belt of Orinoco, Venezuela. This unconventional oil is more expensive to develop and produce, at present, because heavy oil requires more processing to be converted to synthetic crude. Currently, production of one barrel of Saudi Arabian conventional oil costs approximately US$ 5-6, while converting tar sands to synthetic crude costs around US$20-25 per barrel.[h] Profitable economics could only be achieved with technology advances. Thus, investment and technological improvements are recommended to help reduce resource accessibility problems.

[h] Iran-Daily. www.iran-daily.com.

In terms of accessibility, gas can be accessed either through pipelines or shipped as liquefied natural gas (LNG). Similar to oil, the world's natural gas reserves are in remote areas, in terms of relative distance from major consumers. The concern over resource accessibility is, thus, the need for significant transportation infrastructure expansion to bring gas to the final consumption areas.

DEVELOPMENT OF PIPELINE NETWORK SYSTEMS

Traditionally, natural gas trading is conducted via pipeline systems. In the APEC region, these systems are still limited. In North America, a complex pipeline network system exists between the US and Canada and a number of natural gas pipelines exist between the US and Mexico. Among South East Asia members, a Trans-ASEAN Gas Pipeline network has been proposed, however, to date there only exists a short connection between Malaysia and Singapore and another between Indonesia and Singapore. Natural gas pipeline inter-connection systems also exist in South America; for example, Chile has constructed gas supply pipeline networks with Argentina and Bolivia. Another pipeline network connects between Hong Kong and China. Similar pipeline networks have been proposed in North East Asia, from Russia to China and Korea to Japan.

Once these pipeline systems are well developed, they will enhance resource accessibility for the end users; therefore, it will be more beneficial in terms of supply security.

LNG FACILITIES ENHANCEMENT

LNG is another option for economies with limited indigenous resources. Unlike the oil trade, most LNG is traded under long-term supply contracts (20 years or more) [i] which allow direct negotiations between sellers and buyers. In other words, to date, there is no world market for natural gas.

[i] Recently, mid-term contracts of three to ten years have been established (IEEJ 2006).

Natural gas is mainly traded in regional markets. Along the LNG chain, accessibility can be achieved via a significant development of liquefaction plants, LNG ships, and receiving terminals.

In general, there are a number of aspects that must be considered to ensure access to the natural gas or LNG market:

(1) Over the long term trade commitment, substantial assets in production procedures, as well as transport and receiving facilities are required. These capital-intensive investments can be accomplished only if adequate financial support is agreed upon along the gas value chain.

(2) There should be suitable and stable frameworks for contracting and business governance, starting with a mutual commitment on the level of gas supply and demand. Demand stability will incentivise the required infrastructure investment. For such frameworks to be effective, political and socio-economic stability are key.

(3) Regarding gas supply, security is largely dependant on stable delivery and political involvements. In some areas, political intervention may prevent some trade routes from being developed, for example, the supply of new gas from the Caspian Sea to Europe and the pipeline construction project to supply gas from Russia to the North East Asia region.

SAFETY CONCERNS

Unlike European and American markets, which have well-developed pipeline systems, the Asian natural gas market relies on ship transportation.[j] There is an increasing concern over sea lane safety within international trade routes, specifically the Pacific Ocean, the Strait of Malacca and the Indian Ocean. Some of the major routes have narrow sections that are susceptible to piracy, terrorist attacks, or even accidents.

[j] Specific import economies include Japan, Korea, and Chinese Taipei.

WORKFORCE CONSTRAINTS

In addition to LNG trade accessibility, workforce constraints are also a concern since international energy trade will increase in the future. This will expand global energy transportation requirements; as such creating an increase in tanker investments (LNG will have the biggest growth).

As a result, this will amplify the need for more technically qualified seafarers, which are already in short supply. According to a study conducted by the International Association of Maritime Universities, the world's LNG fleet at the end of 2009 will reach 339-354 vessels or more, increasing from 209 LNG vessels in 2006.[k, l, m] By 2009 it is estimated that between 12,870 to 14,040 seafarers will be required to man the LNG fleets worldwide.

[k] The International Association of Maritime Universities. http://www.iamu-edu.org

[l] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.* Tokyo

[m] APEC had a total of 72 LNG fleets in 2006

With the expansion of the LNG fleet and the aging of qualified and skilled steam ship engineers, it is clear that there are not enough engineers to operate the ships. At an international level, LNG tanker crewing has reached a critical point, where demand for LNG tanker officers and engineers has already exceeded supply. According to the Maritime Union of Australia, although "the supply of [workers] exceeds demand in general shipping [at a global level], this is not the case in relation to seafarers qualified to the standards being demanded by reputable LNG tanker operators".[n] In view of this rapid development, human resource capacity is a major concern in the LNG maritime sector.

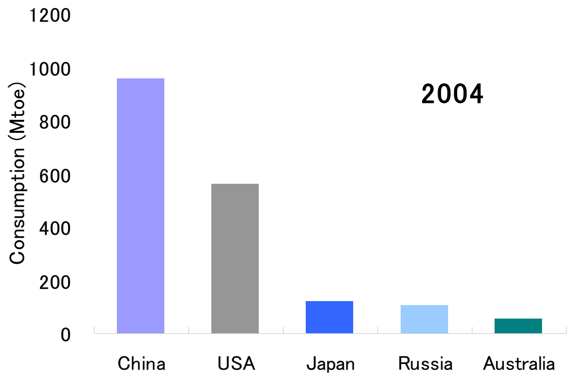
[n] Maritime Union of Australia (2006). *Response to APPEA Issues Paper on Australia's Upstream Oil and Gas Industry.*

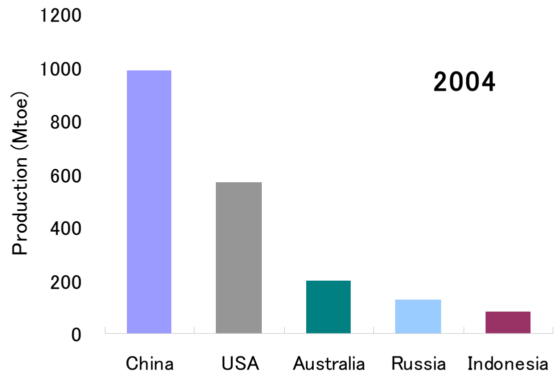
ACCESSIBILITY TO SMALL GAS FIELDS

If a natural gas field is located far from the market and has small reserves, neither pipeline nor LNG transportation can be economically justified to develop it. In such a case, natural gas reserves remain stranded without being developed for production. About half of proven natural gas reserves are considered stranded because of a lack of market access. GTL is a noteworthy option for monetising stranded gas; however, its applications are now limited due to its high capital cost.

COAL

There is not much concern over the accessibility to coal resources. Unlike oil, coal reserves are not concentrated in any specific region; they are distributed in many areas. There is a tendency for coal resources to be used by the producers themselves. For example, in 2004, China and the US were the major coal consumers in the APEC region; combined the economies accounted for 77% of the total coal consumption in the region. China and the US, in 2004, were also the top two producers of coal in the region, accounting for 77% of the coal produced in the APEC region, with production of 900 Mtoe and 567 Mtoe respectively [**23.1, 23.2**].





23.1, 23.2 Top Five Coal Consumer and Producer Economies in the APEC region

BP Statistics 2005

As a result, domestic transportation of coal is prevalent. For domestic consumption, coal is transported by conveyors and trucks for short distances, and railroads and barges for long distances. Coal can also be transported through pipelines when it is mixed with water or oil to form slurry; transportation through pipelines is effective for long distance transportation.

The cost of transportation depends on a number of factors, among others the mine location, transportation distance, and freight availability. The delivery cost of coal for domestic markets is normally 2-3 times the cost of coal mined. In addition, stricter environmental regulation is expected to further increase coal transportation costs.

For international trade, coal is usually transported by ships.[o] In 2003, internationally traded coal accounted for 718 million tonnes; about 18% of the total coal consumed in the world.[p] Since shipping distances are vast, transportation costs represent a large portion of the final coal market price. For example, shipping costs can reach up to 70% of the final coal price.

[o] Roughly 90% of internationally traded coal was transported by ships in 2003.

[p] World Coal Institute. *The Coal Resource: A Comprehensive Overview of Coal.* http://www.kolinstitutet.se/thecoalresource.pdf

NUCLEAR

WORKFORCE CONSTRAINT

The shortage of trained and technically qualified nuclear plant workers is becoming well documented. Since 2000, member economies have conducted a number of national studies to determine their nuclear staffing pipelines status. For example, the US Nuclear Energy Institute[q] (NEI) conducted an industry-wide staffing survey that indicated that the demand for new nuclear workers in the United States will drastically increase. According to the survey, the demand for new workers in the U.S. nuclear industry will be 90,000; of which 26,000 will be required to operate nuclear power plants.[r,s] Angelina S. Howard, the executive vice president of NEI, emphasised that the US needs to “recruit about 40% of [their] plant staffs over the next decade….or about 2,000 workers a year in the near term, and 3,000 a year a decade from now”.[t,u]

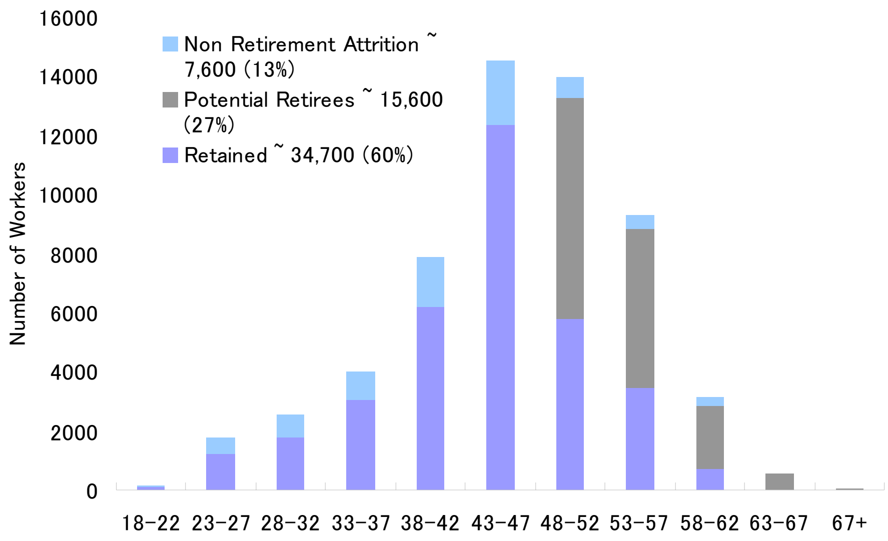
[q] US Nuclear Energy Institute, according to their website, is the policy organisation of the nuclear energy and technologies industry and participates in both the national and global policy-making process.

[r] The workforce demand from related employers, such as engineering design and services and the government sector, is expected to be more than double that of commercial nuclear power facilities

[s] NEI Nuclear Staffing Survey.

[t] Angelina S. Howard (2002). *Developing the New Workforce: It Doesn't Start, or End, with Hiring.* Keynote Address of the Conference on Nuclear Training and Education.

[u] This increase in near term demand is attributed to retirements and a shift in worker stocks, about 55 percent during 2004, to other industries.



24.1 Nuclear General Attrition and Potential Retirees (5 Year Attrition by Age Group)

NEI Nuclear Staffing Survey 2005

Potential retirees are classified as employees that will be older than 53 with at least 25 years of service, older than 63 with 20 years of service, or older than 67 within the next five years.

Likewise, a joint report by the Japan Nuclear Cycle Development Institute and Japan Atomic Industrial Forum, Inc. indicated that during 1990-2002 there was a decline of 6,000 workers from the nuclear industry. During the peak of the nuclear industry in 1990, there was a workforce of 60,000 persons who were engaged in nuclear-related work at utilities and manufacturers; however by 2002 the number had declined to 54,000.[w] Many member economies are experiencing similar trends of an inadequate supply of trained employees to replace departing personnel, thus putting the industry in an awkward position.

[v] The Japan Nuclear Cycle Development Institute (JNC), according to their website, is a research organisation that tries to progress development of the advanced technology required to establish the complete nuclear fuel cycle. The Japan Atomic Industrial Forum, Inc. (JAIF), according to their website, is a comprehensive non-government organisation on nuclear energy that tries to promote nuclear energy development policy.

[w] Japan Nuclear Cycle Development Institute and Japan Atomic Industrial Forum, Inc. 2005.

RENEWABLE ENERGY

FINANCIAL SUBSIDISATION

Renewable energy has several issues that limit accessibility. The first major barrier is that renewable energy's initial capital cost is relatively high compared to conventional fuels. In order to encourage the use of PV systems, which are costly to install, Japan funded R&D to advance PV technology and provided subsidies that reduced financial burden for the installation of PV systems in the residential sector. Similar financial subsidies have been used in the APEC region to further encourage the use of renewable energy technologies.

POLICY PUSH AND MARKET PULL

In addition, accessibility of renewable energy for electricity generation depends on an economy's regulatory framework, whether or not it has consistent policies that promote the use of renewable energy. For example, feed-in tariffs, net-metering, and tax credits can be effective mechanisms to support the deployment of renewable energy. Policies that show a government's commitment to promote renewable energy will help enhance the willingness of investors to develop renewable energy. It is recommended that economies develop policies that provide renewable energy producers with long-term purchase agreements at prices that cover costs.

TECHNOLOGY TRANSFER FROM DEVELOPED ECONOMIES

Developing economies may have limited access to advanced technology, such as PVs, to make the best use of renewable energy. In general, combustible renewables and waste comprise a larger share of total renewable energy within developing economies compared to developed economies. In fact, the use of PV technology and wind energy is limited to niche markets or task-oriented programmes in developing economies, for instance, rural electrification programmes. Technology transfer, from developed economies to developing economies, is recommended to increase developing economies' accessibility to renewable energy.

ACCEPTABILITY

ENVIRONMENTAL CONCERNS

Energy demand in the APEC region is projected to increase nearly three-fold[a], as the region experiences robust economic growth.[b] This energy demand trend is expected to increase energy-related environmental impacts.[c] Faced with this impending problem, policy makers around the world are trying to curb pollution from the energy industry by imposing stricter environmental regulations. Strict environmental regulations combined with enhanced environmental awareness for issues related to the energy sector will create fossil fuel use constraints and affect future energy resources mix.

It is projected that the annual average growth rate for coal will grow the fastest at 2.8% from 2002 to 2030, to reach 3,366 Mtoe in 2030. This accounts for 33% of total primary energy demand. Most of the coal, about 81%, will be used as an input for electricity and heat generation. Second to coal, nuclear is projected at 1.9% annually to reach 643 Mtoe in 2030. All of this nuclear source will be consumed by the electricity generation sector. Nuclear will account for as much as 14% of the total fuel input for electricity and heat generation in 2030.

Therefore, this section will examine environmental concerns related to the energy industry, focusing mainly on three fuel resources -coal, nuclear and unconventional fuels (biofuel and oil sands) - that are touted to be the major energy sources for the century.

[a] From 2,336 Mtoe in 2002 to 6,759 Mtoe in 2030.

[b] GDP is expected to grow 4.1% annually from 2002 to 2030.

[c] Greenhouse gas emissions from the energy industry will increase significantly. For carbon dioxide (CO_2), emissions are estimated to increase almost two-fold, from 15 billion tonnes in 2002 to 27 billion tonnes in 2030, with 47% emitted by the electricity sector. Sulphur dioxide (SO_2) is estimated to increase almost two-fold, from 79 million tonnes in 2002 to 155 million tonnes in 2030. Similarly, nitrogen oxides (NO_X) are estimated to increase from 65 million tonnes in 2002 to 121 million tonnes in 2030, almost a two-fold increase.

COAL

Coal has advantages over other fossil fuels due to its availability, resource locations, and lower, stable prices. The only 'barrier' to coal use is the emissions that arise from coal combustion, specifically carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_X), and mercury.

Recognising this fact, many policy makers in the APEC region have tightened environmental regulations on coal use. For example, in March 2005, the United States introduced two environmental regulations related to coal-fired power plants, the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR), which will be implemented in phases and will eventually replace Title IV of the US Clean Air Act.[d]

CAIR was introduced to control emissions of SO_2 and NO_X though a cap and trade programme. The regulation will be implemented in two phases, with the cap tightening further during Phase II. The target is to cap SO_2 emissions at 3.6 million tons in 2010 and 2.5 million tons in 2015.[e] NO_X emissions will be capped at 1.5 million tons in 2009 and 1.3 millions tons in 2015. Similarly, CAMR was introduced to limit mercury emissions from coal-fired power plants, as coal-fired power plants are the major emitter of mercury in the US. Under the regulation, mercury emissions will be reduced[f] through the use of a cap-and-trade programme. CAMR

[d] Title IV of the US Clean Air Act specifies a reduction in annual emissions of SO_2 to ten million tons (from 1980 emission levels) and a reduction in annual emissions of NO_X to two million tons (from 1980 emission levels).

[e] Due to the cap on SO_2 emissions, coal-based power producers of more than 141 MW in capacity are obliged to installed flue gas desulphurisation equipment.

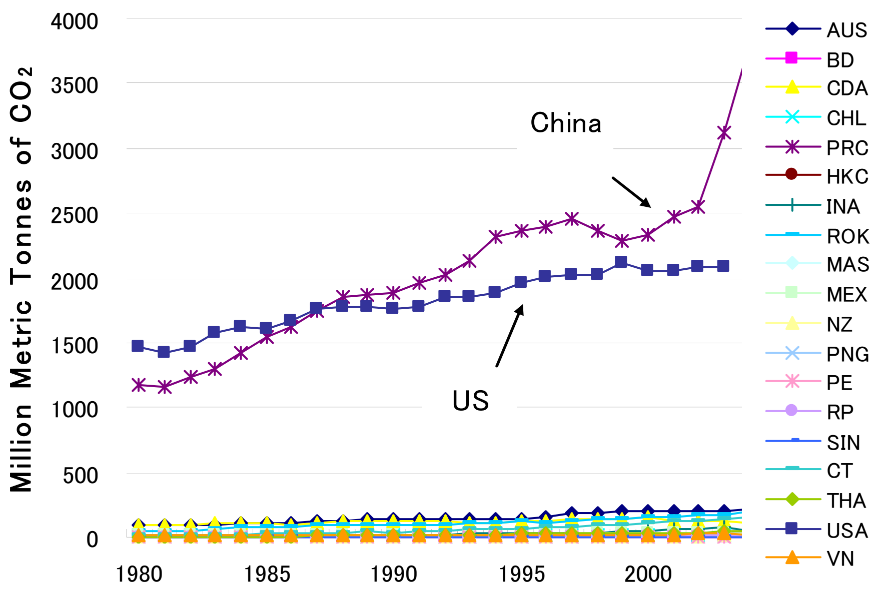
[f] From 48 tons per year (1999 levels) to 15 tons per year in 2018.

will also be implemented in phases; Phase II will have a more stringent cap than Phase I. For the first phase, the target is to cap mercury emissions at 38 tons in 2010. For the second phase, which will commence in 2018, mercury emissions will be capped at 15 tons. These measures will result in a higher cost per unit of electricity price, which will then be passed on to consumers.

Responding to the tightening of environmental regulations, clean coal technologies have been developed for cleaner coal use. As a result, coal use is becoming more complex with the use of high-tech environmental control equipment. Existing clean coal technology can be regarded as relatively proven, in terms of its effectiveness in meeting environmental standards for conventional pollutants, such as SO_2 and NO_X. For example, to control SO_X from being emitted to the atmosphere, coal-fired power plants may use low sulphur coal or install fixed flue gas desulphurisation (FGD) systems that are able to remove almost all SO_X emissions from coal-fired plants.[g] Comparatively, NO_X emissions can be reduced by 80-90% by using selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) technologies. Apart from these technologies, application of fluidised bed combustion (FBC) can also reduce SO_X and NO_X emissions by more than 90%.

[g] Ninety-nine percent of SO_X emissions can be removed by FGD systems.

Besides GHG emissions, coal-fired power plants also emit particulate matter that is detrimental to human health and the environment. To control this pollutant, electrostatic precipitators and fabric filters, which can remove up to 99.5% of total particulate emissions, are used.



28.1 **APEC Carbon Dioxide Emissions from Coal Consumption, 1980-2004**

US Energy Information Administration 2004

Coal is not used in Brunei Darussalam and Papua New Guinea.

Unfortunately, existing proven clean coal technologies cannot resolve the problem of CO_2 emissions, the main culprit of global climate change, from coal use. From 1980 to 2004, carbon dioxide emissions from the consumption of coal have increased almost 1.8 times, from 3,106 million metric tonnes in 1980 to 5,584 million metric tonnes in 2004, with an annual average growth rate of 2.47%. China and the US were the major emitters of carbon dioxide in the region, accounting for about 75% of the carbon dioxide emitted from coal use in 2003 [28.1]. Furthermore, carbon dioxide emissions from coal consumption in China have experienced a rapid growth, particularly from 2000 to 2004, with an annual average growth rate of 12.96%. This resulted from rapid economic growth, 9.37% per year from 2000 to 2004, which catalysed an increase in total primary coal consumption from 637 Mtoe in 2000 to 993 Mtoe in 2004.[h]

Since there is increasing concern over the role of CO_2 in global climate change and the increase in CO_2 emissions from coal use, industry is now compelled to tackle the CO_2 emissions problem. Subsequently, Carbon Capture and Sequestration (CCS) technology (See Box on the next page), which enables the capture and storage of CO_2 so that it is not to released into the atmosphere, has been explored. However, as with other new technologies and innovations, further analysis still has to be carried out to confirm the effectiveness and the safety of the technology. This development process is also plagued with high technological risk and high capital costs.

In addition to technological uncertainties, CCS technology will increase the cost of generated electricity. The cost of electricity generation per kWh in power plants with CO_2 capture and geological storage will increase between 43-91% for pulverised coal power plants and between 21-78% for IGCC [29.1]. The cost increase of electricity generated from power plants with carbon capture and enhanced oil recovery is slightly lower, between 12-57% for pulverised coal power plants and -10-46% for IGCC. This extra cost will be passed on to consumers; hence striving for acceptability may result in reducing the price advantage of coal over other conventional fossil fuels.

[h] Institute of Energy Economics Japan (2007). *EDMC; Handbook of Energy & Economic Statistics in Japan*

Power Plants Performance and Cost Parameters[1]	**Pulverised Coal Power Plant**	**Integrated Coal Gasification Combined Cycle Power Plant**
Reference plant without CCS		
Cost of electricity (US$/kWh)	0.043 – 0.052	0.041 – 0.061
Power plant with capture		
Increased fuel requirement (%)	24 – 40	14 – 25
Power plant with capture and geological storage[2]		
Cost of electricity (US$/kWh)	0.063 – 0.099	0.055 – 0.091
Cost of CCS (US$/kWh)	0.019 – 0.047	0.010 – 0.032
% increase in cost of electricity	43 – 91	21 – 78
Power plant with capture and enhanced oil recovery[3]		
Cost of electricity (US$/kWh)	0.049 – 0.081	0.040 – 0.075
Cost of CCS (US$/kWh)	0.005 – 0.029	(-0.005) – 0.0019
% increase in cost of electricity	12 – 57	(-10) – 46

29.1 Range of Total Cost of CO2 Capture, Transport and Geological Storage Based on Current Technology for New Power Plants Using Bituminous Coal

IPCC, Carbon Dioxide Capture and Storage; Summary for Policymakers and Technical Summary

[1] All changes are relative to a similar power plant without CCS
[2] Transport costs range from 0 – 5 US$/t$CO_2$; geological storage costs range from 0.6 – 8.3 US$/t$CO_2$.
[3] Same capture and transport costs as above; net storage costs for EOR range from -10 to -16 US$/tCO2 (based on pre-2003 oil prices of 15 – 20 US$ per barrel)

Brief Description of Carbon Capture and Sequestration (CCS) technology

Source: Herzog.H, Golomb. D. (2004), Massachusetts Institute of Technology Laboratory for Energy and the Environment, *Carbon Capture and Storage from Fossil Fuel Use*

As indicated by the name, this technology involves the capturing and storing of CO_2. There are three methods to capture CO_2 from coal-fired power plants.

(1) **Flue gas separation**. CO_2 capture using the flue gas separation process involves a chemical absorption process. The process is capital and energy intensive and it requires a substantial amount of energy input from the power plant, as solvent is required to be cooled and heated. Due to its high cost, this process is currently only being applied in less than 20 facilities around the world that use the CO_2 captured as a commercial commodity.

(2) **Oxygen fired pulverised coal (Oxy-fuel) combustion**. This process can be applied to an existing pulverised coal power plant and only requires an air separation unit (ASU) to be installed to separate oxygen from nitrogen in the intake air. However, the ASU unit requires about 15% of the power plant's total electricity output.

(3) **Pre-combustion capture**. This process is suitable for coal combustion combined cycle (IGCC) power plants. As the name implies, in this process CO_2 is captured before combustion takes place. However, electricity produced from pulverised coal fired power plants (PC) is more economical, making a wide application of this method unlikely.

As for CO_2 storage, there are few means to store CO_2. In order to select the most appropriate media, several factors need to be considered, such as storage period; storage cost, including the cost of transportation from the source to the storage location; possible accident risks; environmental impacts; and national or international laws and regulations.

The methods to store CO_2 captured are listed below:

(1) **Geological sinks**. There are several types of geological sinks, such as deep saline formations, Enhance Oil Recovery (EOR), and unminable coal seams. However, geological seams have environmental and safety concerns, such as whether buried CO_2 will stay put, how to monitor stored CO_2, and environmental impacts of stored CO_2 leakage. Therefore, further study is recommended, so as to ascertain the effects of geological CO_2 sinks to the environment and human health by determining the possibility and impacts of leakage, slow migration and accumulation of $CO_{2,}$ or induced seismology.

(2) **Ocean storage**. There are two leading methods: injecting CO_2 at mid depth (1500 to 3000m) where the dissolution of CO_2 is expected to happen in the mid depth, and injecting CO_2 below 3000m where CO_2 is expected to form a 'deep lake'. For the former method, as the dilution level is high the local environmental impact is expected to be minimised, but the location of the injection point is important. However, there are environmental concerns about the impacts of the latter method; where the formation of high concentrations of CO_2 in the deep ocean can increase the acidity level of the water and affect the micro organisms that inhibit the area.

(3) **Biological carbon sequestration**. The main method is through large scale plantations of trees or afforestation. At first, afforestation appeared to be both effective and environmentally friendly since planted trees will sequester CO_2 as long as they are alive. However, there are advantages and disadvantages of the afforestation method. One advantage of afforestation, through the conversion of crops land to forest, is water quality improvement through nutrient and pesticide reductions. However, one disadvantage of this method is that extensive afforestation may bring negative impacts to the environment, such as reduction of stream flow (on average by one-third or three-quarter). Consequently, it is important to determine tree species and the area of afforestation, as it will affect runoff and stream flow. Furthermore, afforestration may also alter the chemistry of soil that will affect soil fertility and sustainability.

NUCLEAR

Nuclear power generation is considered to be one of the most environmentally friendly power generation methods because nuclear power plants do not produce any combustion by-products, such as CO_2, SO_2, and NO_X. Consequently, use of nuclear power generation, instead of conventional fossil fuel-based power plants, can help to mitigate the amount of emitted GHGs. For example, in the US, nuclear power plants have avoided 1.1 million short tonnes of NO_X emissions in 2005 (equivalent to the amount emitted by 55 million passenger vehicles in a year), 3.3 million short tonnes of SO_2 (more than double the avoided SO_2 emissions from hydroelectric power and all other renewable energy sources combined), and has avoided CO_2 emissions equivalent to the amount released by all US passenger vehicles combined.[i]

[i] Nuclear Energy Institute 2006

On the other hand, the nuclear fuel process chain does cause some negative environmental impacts. For example, mining of uranium may cause toxic contamination of local land and water resources. Uranium mines also pose radioactive contamination hazards to mine workers and to nearby populations, and abandoned mines will be contaminated with high-level radioactive waste. It is reported that radioactive risks continue for as long as 250,000 years.[j] Furthermore, heavy metals and traces of radioactive uranium that are contained in the waste generated from uranium mining operations and rainwater runoff can contaminate groundwater and surface water resources.

[j] Power Scorecard, Electricity from: Nuclear Power, (http://www.powerscorecard.org/tech_detail.cfm?resource_id=7)

In addition, some segments of the nuclear fuel process chain, i.e. uranium mining and uranium enrichment processing, requires a significant amount of electricity (usually generated by fossil fuel), which will increase GHG emissions. Therefore, nuclear power generation does indirectly contribute to GHG emissions along its process chain.

Moreover, nuclear power plants' cooling systems require substantial amounts of water, about two-and-a-half times as much water as for conventional fossil fuel plants.[j] Consequently, more significant impacts to water resources, aquatic life, and habitats are expected.

As for the nuclear power generation process, water discharge from nuclear power plants may negatively affect water quality and aquatic life due to its higher temperature and build up of heavy metals and salts. Nuclear power plants also generate radioactive nuclear solid waste that needs to be stored in special sites that need to be adequately sealed to minimise the risk of radioactive release, which could pose a serious health hazard. For example, the US has a plan to store its radioactive nuclear waste in a geological layer in Yucca Mountain,[k] while Japan is conducting a site selection study for suitable geological storage of nuclear waste that is expected to start operation in 2030.

[k] Yucca Mountain is expected to receive the first shipment of radioactive waste in 2017 (Eureka County Yucca Mountain Information Office: Nuclear Waste Update, winter 2007, Volume XII, Issue 1)

There are also environmental impacts associated with the decommissioning of nuclear power plants; for example, nuclear power plant equipment that is contaminated with radiation will become radioactive waste after power plant decommissioning, staying radioactive for thousands of years.

BIOFUELS

Biofuel, while admittedly a viable and attractive alternative fuel because of high oil prices, depleting fossil fuel resources, and its ability to mitigate CO_2 emissions to the atmosphere, will cause diverse unintended negative environmental impacts during production. One of the environmental impacts arises from significant water requirements, which is a scarce resource in some places,[l] of the biofuel crops and biofuel production. For example, in the US, approximately 600 -800 tonnes of water are required to grow one tonne of sugar cane, while 13 to 28 litres of water are needed by ethanol plants to produce 3.8 litres of bioethanol.[m] Since bioethanol production is expected to increase robustly in the future, water consumed by this industry is also expected to rise rapidly; for instance in Minnesota, the volume of water used in ethanol production is projected to increase 254% from 1998 to 2008. Consequently, water use conflicts will escalate between farmers and urban residents, and also between the ethanol industry and other industries. Additional water requirements for biofuel crops will also threaten food security and may cause an increase in food prices in certain economies. For example, in China,[n] a shortage of underground water supply due to overexploitation in the North China Plain – which supplies more than half of China's wheat and one third of its corn – has resulted in difficulties to grow grains, which in turn has caused concern that China's demand for grains could have a big impact on grain prices in the global market.

[l] For example, in the United States, although it has plenty of water on national basis, groundwater reserves are being depleted in many areas. Particularly, in the western part of the economy, groundwater aquifers are being depleted at faster rates than other areas. For instance, the Ogallala aquifer, which covers parts of six states - Colorado, Kansas, New Mexico, Oklahoma, Texas, and Nebraska - and irrigates 6 million hectares, has been over exploited. (Hinrichsen, et al. 1998)

[m] Institute for Agriculture and Trade Policy 2006

[n] The world's third largest bio-ethanol producer and consumer

Similarly, food supply may also be threatened by utilisation of crops for fuel feedstock. It was reported that to produce about 12.9 billion litres of bioethanol in 2004, the US bioethanol industry consumed 32 million tonnes of corn, which was enough to feed 100 million people.[o] The competition between food feedstocks and fuel feedstocks may also cause an increase in food prices, which may lead to social unrest in some economies. For example, in early 2007, street protests were staged in Mexico's capital to protest against the price increases on their staple food – tortillas, a corn based product.[p] Tortilla prices increased as high as US$1.76 per kilogram from US$0.58 per kilogram. Since approximately one-half of the Mexican population lives on US $6.45 per day, the impact of this price increase is very significant.[q]

[o] Lester R. Brown, (2006). *Plan 2.0 Rescuing a Planet Under Stress and a Civilisation in Trouble.*

[p] Mexico imports about 25% of corn from the US (The New York Times, Thousands in Mexico City Protest Rising Food Prises, 1 February 2007)

[q] Reuters, *Thousands March Over Tortilla Crisis*, 1 February 2007.

Other environmental impacts from biofuel development are deforestation, forest fires, threat to plants and animal diversity, and habitat fragmentation. This problem arises in the initial process of opening and preparing land for crop plantations, which sometimes leads to forest slash and burns that can cause smog problems. For example, between 1997 and 1998, land clearing for palm oil plantations in Indonesia contributed to forest fires which caused serious smog problems domestically and in neighbouring economies (Malaysia, Brunei Darussalam, and Singapore).[r]

[r] It is estimated that emissions from the forest fires in Indonesia between 1997-1998 emitted the equivalent of 13 -40% of global carbon emissions from the burning of fossil fuel in the same period. (Nature 2002)

OIL SANDS

Oil sands, referred to as tar sands or bituminous sands, represent as much as 66% of the world's total reserves. Three quarters of the world's oil sand reserves are found in Canada[s] and Venezuela. Following Saudi Arabia, Canada is ranked the second largest in terms of global proven crude oil reserves, the majority of which are found in Alberta's oil sands. Alberta currently has about 174 billion barrels of crude bitumen and 1.6 billion barrels of crude oil.[t]

[s] Mostly in Athabasca which is located in northern Alberta and Saskatchewan, Canada.

[t] National Energy Board, Canada (2006). *Canada's Oil Sands Opportunities and Challenges to 2015: An update.*

The Oil sands industry has significant environmental impacts, compared to conventional oil, resulting from its huge water requirement and higher rate of GHG emissions. The Athabasca River, which is the main source of water supply for oil sand development in Alberta, may not be able to supply adequate water for future oil sand production.[u,v] This is because oil sands development, both mining and in situ, requires substantial volumes of water; 2-4.5 barrels of water are needed to produce each barrel of synthetic crude oil (SCO) and less than 10% of the water used is returned to the river because the water becomes heavily polluted in the process and the rest is held in tailings in ponds. In addition, the in situ process also affects the groundwater level of adjacent areas which in turn cause reduced groundwater flow to other surface water bodies.[w] As for GHG emissions, production of bitumen and SCO emit more GHG emissions than conventional oil production. It is reported by the Pembina Institute that GHG emissions from oil sands production is the largest contributor to GHG emission growth in Canada and could account for 47% of the projected growth of Canada's total emissions between 2003 and 2010.[w,x]

[u] In 1995, the Alberta State government set a target to produce one million bpd of oil sands by 2020. However, attractive incentives offered by the Alberta State government facilitated the rapid development of oil sands projects in Alberta that resulted in production reaching 1.1 million bpd in 2004 – surpassing the targeted value of 1 million bpd set for 2020 (Canadian Association of Petroleum Products 2006)

[v] As of June 2006, 370 MCM of freshwater per year were licensed to be diverted from the Athabasca River for developments of the approved oils sands projects, while the planned oil sands mines will account for the cumulative withdrawal of 529 MCM of freshwater from the Athabasca River. (National Energy Board, Canada (2006). *Canada's Oil Sands Opportunities and Challenges to 2015: An update)*

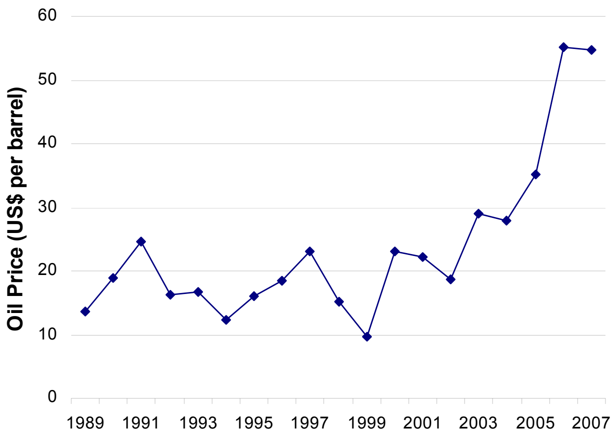
[w] Pembina Institute Canada. (2006).Oil Sand Fever – The Environmental Implications of Canada's Oil Sand Rush

[x] Projected growth based on BAU

AFFORDABILITY

OIL

Historical trends show a high degree of oil price volatility. World crude oil price, as shown in [35.1], has fluctuated erratically from 1969 to 2007. Several factors contribute to these fluctuations. For instance, geopolitical issues, which may result in potential supply disruptions, are one of the major concerns for securing supply. Imbalances between demand and supply result in unavoidable lags that influence oil price and impede the precise forecast of long-term demand and supply. Furthermore, a vicious circle of insecurity is caused by unstable oil prices that hinder upstream investment, which in turn cause uncertainty about future supply.



35.1 Historical Trend of Oil Price

Energy Information Administration. USA.

Spot price FOB is weighted by the estimated export volume (US$ per barrel)

Major oil companies play a crucial role in influencing oil price. Investment in oil and gas upstream exploration and development is highly correlated with oil price movements, which are affected by the timing of major oil companies' investment.[a] Exploration costs dominate the majors' capital expenditures, as shown in Table [35.2], the share increased from 67.4% in 2001 to 74.4% in 2005. This trend is indicative of recent increased oil prices.

[a] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

During periods of high oil price, investment in the oil sector is more encouraged for stable oil supply and prices. International oil companies (IOCs) and national oil companies (NOCs), which cumulatively own almost 80% of the world's proven reserves, have to face different investment impediments. IOCs have limited access to reserves and are critically influenced by host government's policies, such as taxation, licensing, and royalties. NOCs, on the other hand, have to deal with limited funding, expertise and technology. Therefore, cooperation between IOCs and NOCs - which is not common at present - could lead to higher investment levels if the venture's production risks and returns are properly shared.[b]

	2001	2002	2003	2004	2005
Capital expenditure	56,643	68,084	57,866	61,629	72,596
Exploration (share in capital expenditure)	38,165 (67.4%)	45,507 (66.8%)	41,446 (71.6%)	44,270 (71.8%)	54,045 (74.4%)

35.2 Capital expenditure of the major oil companies, 2001-2005 (US$ million)

OPEC Annual Statistical Bulletin 2005

According to IEA, most companies make their investment decisions based on a long-term price of US$ 20-25 per barrel.[c] It is likely that technology advancement will encourage oil companies to invest in non-conventional sources that were previously uneconomic. If technology advancement enables reserves that currently cost more than conventional oil resources to develop within an affordable range, investment will be facilitated and future reserves will be significantly different.

[b] International Monetary Fund (2006). *World Economic Outlook 2006.*

[c] International Energy Agency (2005). Oil & Gas Technologies for the Energy Markets of the Future.

In addition, one effective way to enhance energy security is to have oil stocks that can function as a buffer against oil supply/price shocks. Strategic oil stocks are especially important for oil importing economies, which are

[d] As of 2007, Chinese Taipei, Korea, Japan, and the US are equipped with strategic oil stocks in the APEC region.

vulnerable to disruptions. Commercial oil stocks are observed in many economies, however, few economies have strategic oil stocks.[d] High capital cost is one reason why economies, particularly developing economies, are reluctant to construct strategic oil stocks. As clearly shown in [36.1], capital costs make up a substantial portion in the estimated costs of oil storage facilities. Similar to resource exploration, technology advancement is recommended to make oil stocks affordable for developing economies, as well as developed economies.

Capital Cost (US$/bbl)	5.51 ~ 15.68
Operation & Management Cost (US$/bbl-yr)	0.09 ~ 0.17
Fill/Refill Cost (US$/bbl)	0.05 ~ 0.09
Drawdown Cost (US$/bbl)	0.07 ~ 0.10
Facility Size (MMB)	100
Maximum Drawdown Rate (MMBD)	1.17
Maximum Fill Rate (MMBD)	0.27
Development Time (years)	8 ~ 13

36.1 Estimated Costs of Constructing Oil Storage Facilities

APERC 2000

Estimated costs have a range because three different technologies - in-ground trench, hard rock mine, and salt caverns - are taken into consideration and costs are estimated for each.

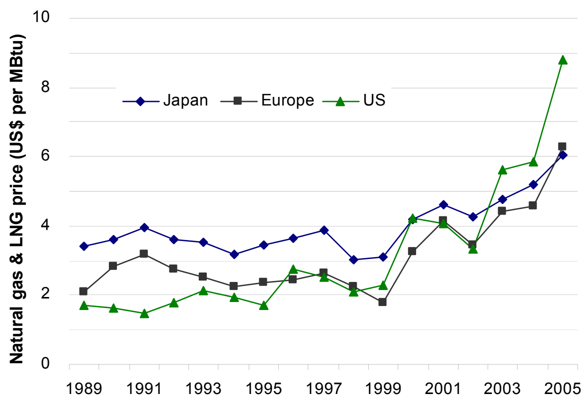
NATURAL GAS

Natural gas price has been increasing in recent years [36.2]. Historically, the LNG price in Japan, which is influenced by the availability of LNG tankers, has been higher than the natural gas price in the US and Europe. However, such a regional difference has been narrowed recently; one of the reasons could be the rapid growth in Middle East LNG supply.

In spite of the recent trend in rising natural gas price, the Energy Information Agency (EIA) has projected that US natural gas price will begin to decline until 2015 and then stay around US$5-6 per million Btu through 2030 [37.1].[e] Nevertheless, the natural gas price forecast might be adjusted in the future to mimic oil price movements, since natural gas price has a strong linkage with oil price.

In addition to moderately stable natural gas price projections, costs related to LNG infrastructure have also been decreasing. EIA's study reveals that plant capital costs, re-gasification terminal costs, and liquefaction costs, (which represent the largest cost in the LNG value chain) have declined.[f] Specifically, liquefaction costs have decreased 35-50% over the past ten years. Additionally, building costs for LNG tankers (138,000m³) have also decreased, from US$280 million in 1995 to US$150-160 million in 2007.[g]

Currently, LNG shipping capacity is a major



36.2 Historical trend of natural gas and LNG price

Japan Oil, Gas and Metal National Corporation

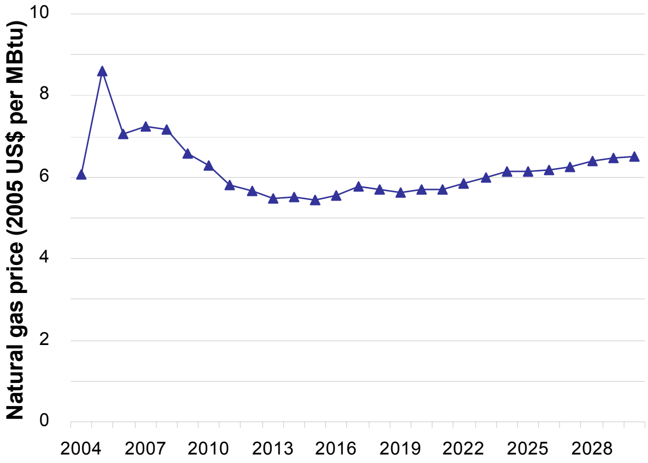
Japan, LNG cif price; Europe, natural gas Union cif price; US, natural gas Henry Hub cif price.

[e] The expected price range will converge with the expected prices in Europe and Japan.

[f] LNG plant costs are relatively higher than other comparable energy projects due to remote locations, strict design and safety standards, the requirement of large amounts of cryogenic material, and a historic tendency to over-design to ensure supply security. Plant capital costs decreased from more than US$500 per ton annual liquefaction capacity to less than US$200 for trains at existing plants: EIA (2003). *The Global Liquefied Natural Gas Market: Status & Outlook.*

[g] EIA (2003). *The Global Liquefied Natural Gas Market: Status & Outlook.*

constraint, in terms of securing LNG supply. Decreasing LNG tanker construction costs, however, is expected to see an increase in the number of new LNG tankers, which will therefore raise total fleet capacity in the future.

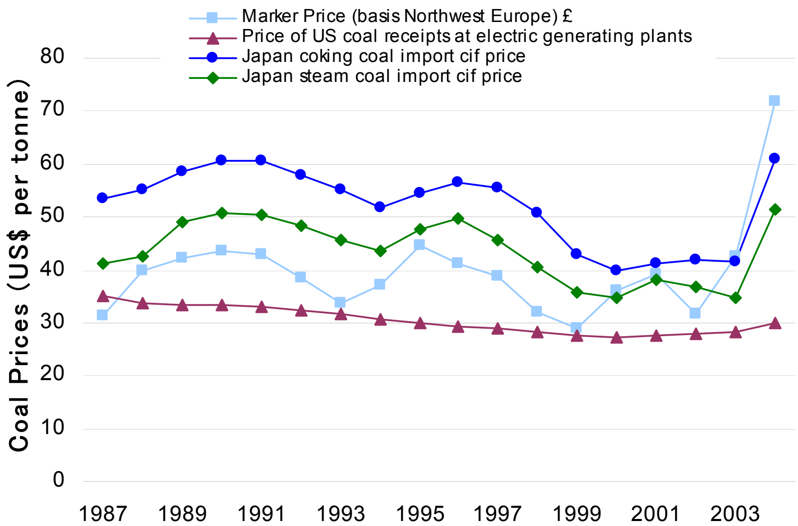


37.1 **US natural gas price forecast (Henry Hub spot price)**

Energy Information Administration

COAL

Compared to the prices of oil and gas, coal price is considered to be cost competitive. Coal prices have been relatively stable (in the long term), until tighter demand and supply balance led to a drastic increase in 2004 [37.2]. Coal's affordability can be discussed from two investment angles: coal production and transportation, and sustainable coal development to reduce its environmental impacts.



37.2 **Historical trend of coal price**

British Petroleum (2006). BP Statistical Review of World Energy 2005.

£ Source of Marker Price: McCloskey Coal Information Service
Note: cif = cost + insurance + freight (average prices)

Among energy resources, coal requires the least investment; accounting for only 5% of the cumulative energy investment estimated between 2003 and 2030 for the APEC region. However, some economies, such as China, USA, Australia, and Indonesia, require substantial investments in coal production and transportation. In fact, those economies are expected to have the highest investment burden with respect to cumulative GDP [38.1].

To achieve an economic and environmental balance, coal use is subject to additional costs. For example, to avoid CO_2 from being released to the atmosphere, the use of carbon capture and storage (CCS) technology by industries that use coal is recommended. The application of this technology for coal fired power plants, however, will incur additional costs -within US$15-75 per tonne of net CO_2 captured- that will eventually reduce coal's price advantage over other fossil fuels. As for CO_2 storage costs, it depends on the storage medium; ocean storage will be much more expensive than geological storage [38.2].

	Cumulative Investment from 2003 to 2030 (2000 US$ billion)	**Share of Cumulative Investment to Cumulative GDP, 2003 - 2030 (%)**
China	Between 188.5 to 232.5	0.042 to 0.052
United States	Between 67.1 to 73.2	0.015 to 0.016
Australia	Between 40.3 to 46.1	0.182 to 0.208
Indonesia	Between 10.5 to 14.0	0.023 to 0.030
Russia	Between 9.1 to 9.6	0.010 to 0.011
Vietnam	Between 4.2 to 5.6	0.026 to 0.034
Canada	Between 4.1 to 4.5	0.010 to 0.011
Mexico	Between 0.7 to 0.9	0.001 to 0.002
Philippines	Between 0.7 to 0.9	0.005 to 0.007
Thailand	Between 0.5 to 0.7	0.002 to 0.002
New Zealand	Between 0.3 to 0.3	0.008 to 0.009
Total	**Between 326 to 388**	

38.1 **Estimated investment in coal production and transportation**

APERC (2006). *APEC Energy Demand and Supply Outlook.*

CCS system Components	**Cost Ranges**	**Remarks**
Capture from coal-fired power plant	15 – 75 US$/t$CO_2$ net captured	Net cost of captured CO_2, compared to the same plant without capture.
Transportation	1 -8 US$/t$CO_2$ transported	Per 250 km pipeline or for shipping mass flow rates of 5-40 MtCO_2 per year
Geological storage*	0.5 – 8 US$/t$CO_2$ net injected	Excluding potential revenues from EOR or ECBM
Geological storage: monitoring and verification	0.1 – 0.3 US$/t$CO_2$ injected	Covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory requirements
Ocean storage	5 – 30 US$/t$CO_2$ net injected	Including the offshore transportation of 100-500 km, excluding monitoring and verification
Mineral carbonation	50- 100 US$/t$CO_2$ net mineralised	Range of the best case studied. Includes additional energy use for carbonation.

38.2 **Cost range of CCS system components, 2002**

IPCC (Carbon Dioxide Capture and Storage; Summary for Policymakers and Technical Summary)

All numbers are representative of the costs for large-scale, new installations, with coal prices assumed to be 1 – 1.5 US$ per GJ.

** Over the long term, there may be additional costs for remediation and liabilities*

To analyse nuclear power plant costs, it is necessary to look at construction, operation and maintenance (O&M), and fuel costs.[h] It is a well-known fact that nuclear power plants have higher capital costs compared to fossil fuel based plants. Nuclear overnight construction costs range from US$1,000 to 2,000/kW while coal plants cost at US$1,000 – 1,500/kW and gas plants US$400 – 800/kW.[i] This is because it is necessary for nuclear power plants to use special materials, sophisticated safety features, and back-up control equipment for safety reasons.[j]

[h] Including waste and decommissioning costs

[i] International Energy Agency (2005). *Projected Costs of Generating Electricity – 2005 Update.*

[j] Overnight construction costs include expenditure on the necessary equipment, engineering and labour, and they are exclusive of interest yielding during the construction period. World Nuclear Association (2007). *The Economics of Nuclear Power.*

In addition to high capital costs, prolonged construction periods- resulting from regulatory delay, redesign requirements, and quality control- increase construction costs. However, some economies (the US and Japan) have standardised the regulatory process for siting, licensing, and construction of nuclear power plants. This kind of administrative support is expected to shorten the construction time period, which will eventually result in cost reductions.

Once the power plant construction phase is complete, the other costs (O&M and fuel) are competitive with fossil fuel based power plants. In the US, for example, nuclear production costs have been decreasing since 1985 [39.1]. This is because streamlined procedures have made O&M regulatory requirements less burdensome, as such reducing costs. In addition, fuel costs have also been declining significantly since 1985.

One of advantages of nuclear power plants is that fuel costs account for a small percentage of the total electricity cost, about 5%, hence overall costs are not highly affected by fuel price fluctuations. Furthermore, technological progress and innovation in enrichment and spent fuel management can potentially help reduce fuel service costs further.[k]

	1981	1985	1990	1995	2000	2003
O&M costs	1.41	1.93	2.07	1.73	1.37	1.28
Fuel costs	1.06	1.28	1.01	0.69	0.52	0.44
Total	2.47	3.21	3.08	2.42	1.89	1.72

39.1 Average US nuclear production costs, 1981-2003 (2003 cents per kWh)

World Nuclear Association

[k] World Nuclear Association http://www.world-nuclear.org/info/inf02.html

On the whole, nuclear power's high capital costs are offset by relatively competitive O&M and fuel costs. The economics of nuclear power generation might be less attractive because nuclear power plants have to deal with many regulations, whereas gas-fired and coal-fired plants do not face such vigorous regulations. Possible reductions in construction and O&M costs are dependant on the efficiency of regulatory procedures; nevertheless, this efficiency should never compromise safety.

RENEWABLE ENERGY

Cost competitiveness is a major challenge for renewable energy. In general, the average renewable energy cost is higher than that of conventional fuels. Although several renewable energy options, such as large-scale hydropower and combustible biomass, have become competitive with fossil fuel prices, cost reductions of renewable energy development still remain a critical issue. Renewable energies cost more than fossil fuels, in terms of specific overnight construction costs and generation costs [40.1]. High up-front capital costs are a deterrence for renewable energy proliferation. Nevertheless, if external costs are taken into consideration, renewable energy still proves beneficial to develop and use because is has fewer externalities than fossil fuels.

	Specific overnight construction costs[i]	Generation costs[i]		External costs[ii]
	US$/kW	5% discount US$/MWh	10% discount US$/MWh	US$/MWh
Coal	1000 - 1500	25 - 50	35 - 60	85
Gas	400 - 800	37 - 60	40 - 63	25
Nuclear	1000 - 2000	21 - 31	30 - 50	4.5
Hydro	1600 - 6800	40 - 80	65 - 100	5
Wind	1000 - 2000	35 - 95	45 - 140	2.5
Photovoltaic	3000 - 11000	150	200	6

40.1 **Comparison on electricity generation costs and external costs**

(i) International Energy Agency (2005). Projected Costs of Generating Electricity – 2005 Update and (ii) APERC (2005). Renewable Electricity in the APEC Region: Externalities in Power Generation.

The levelised lifetime cost approach was used to calculate construction and generation costs. The components for this calculation were: economic lifetime (40 years), average load factor for base-load plants (85%), and discount rates (5% and 10%).

Projections suggest that the capital and generation cost gap between fossil fuels and renewable energy is narrowing. Renewables' investment and generation costs exhibit a gradual decrease, between 2002 and 2010 [40.2]. While costs of renewable energy could vary depending on geographical context, technology advancement is considered an effective way to help reduce costs. To make renewables affordable and competitive in the future, investments in R&D and technology transfer are recommended.

	Investment costs		Generation costs	
	US$/kW		US$/MWh	
	2002	**2010**	**2002**	**2010**
Small hydro	1000 ~ 5000	950 ~ 4500	20 - 30 ~ 90-150	20 ~ 80 -130
Wind	850 ~ 1700	700 ~ 1300	30 - 50 ~ 100 -120	20 - 40 ~ 60 - 90
Biomass	500 ~ 4000	400 ~ 3000	20 - 30 ~ 100 -150	20 ~ 80 -100
PV	4500 ~ 7000	3000 ~ 4500	180 - 200 ~ 250 -800	100 -150 ~ 180 - 400

40.2 **Investment and generation costs of renewables, 2002 and 2010**

International Energy Agency (2003). *Renewables for Power Generation – Status & Prospects.*

CONCLUSION

This chapter reviewed, from the 4 A's perspective, the long term energy resource supply security of the APEC region.

OIL

The main study finding is that oil supply security is now jeopardised by accessibility barriers, especially geopolitical factors. And because of this, supply risk could turn into reality as early as the next few decades when non- OPEC supply fails to meet growing global demand.

It is therefore essential for us to take this risk seriously, even though it is difficult to predict the timing of global oil peak arrival with a reasonable accuracy because of unreliable data involved in reserves and resource estimates.

In terms of availability, conventional oil is still abundant enough to remain an important energy source. As shown from the study, the R/P ratio extends to 80 years -from 41 years- if all recoverable resources become available as projected by USGS. In addition, the expected amount of non-conventional oil resource base, which could becomes reserves in the future, is huge. Oil sands, for example, have already become affordable oil resources.

It is, therefore, conceivable that oil could continue to be used into the 21st century, as one of the main energy sources, if accessibility problems are solved, and smooth transition from conventional oil to unconventional oil is made under proper policy measures.

NATURAL GAS

As for natural gas, it is more reliable than oil in terms of availability, as well as accessibility (geographical), because gas resources have not yet been developed as extensively as oil resources and they are more widely distributed globally. Non- conventional gas resources are also abundant. Tight sand gas, in the US, for example, has already become an important gas supply source.

In terms of accessibility barriers, like huge infrastructure investments and long term sales contracts, gas is at a disadvantage to oil, but it is manageable because it is not as fundamental of a barrier as geopolitical accessibility is to oil.

Natural gas is the cleanest and easiest to use among fossil fuels. Because of this acceptability and affordability, demand is projected to grow especially in the electricity, industry, commercial, and residential sectors.

COAL

Estimated coal reserves worldwide are large and therefore are expected to serve global needs well throughout this century, even though a temporary regional supply shortage may occur because of supply /demand imbalance. In terms of accessibility as well as affordability, coal is also in an advantageous position over other fossil fuels.

The main barrier to coal use is its environmental sustainability. The risk of global climate change from GHG emissions, which have been linked to the use of fossil fuels, in particular coal, is now growing and generating enormous public interest world wide.

Carbon capture and storage (CCS) technology is considered a promising technology for drastically reducing CO_2 emissions, if applied at large power plants which burn fossil fuels. However, there is still a long way to go for this option to be accepted as a reliable and affordable. Further technology development and commercialisation is one solution to solve the acceptability issue of coal.

NUCLEAR

Nuclear power has established itself as a potential energy supply option in some APEC member economies. Its advantages over competing fuels, in terms of availability, affordability, and environmental aspects (pollutants and GHG emissions free) give nuclear energy a competitive edge.

Against the backdrop of heightened energy supply security concerns and global climate change issues, the aforementioned characteristics have sparked a renewed interest in nuclear energy worldwide, particularly in the APEC region. However, there exist nuclear specific concerns, namely: operational safety, proliferation, terrorism, radioactive waste disposal, and the resulting public acceptance issues (acceptability).

In response to these challenges, many economies are now working to enhance safety; waste management; and to develop proliferation resistant advanced nuclear reactors, such as the Generation IV Nuclear Development. Technology innovation will play an essential role in making nuclear an effective energy option for the 21st century and beyond.

NEW & RENEWABLE ENERGY

The NRE and hydro energy resource base is sufficient to cover the world's current primary energy consumption. However, there are still some specific physical constraints, such as weather dependence and low energy supply density. For example, solar/wind power plants have 1/500 the power generation density per square meter of fossil fuel/ nuclear power plants and 1/100 of hydro power plants. Therefore, NRE and hydro energy are affordable on a local scale, but not as a major energy supply resource.

Bio-fuels, similarly, have supply capacity constraints; therefore, its potential role as a substitute for conventional transportation fuels is limited. However, its importance is growing as a result of energy supply security concerns. Further technology development will help limit reduce these limitations in the future.

ENERGY SECURITY INDICATORS

INTRODUCTION

Long term energy supply security is contingent on the establishment of "efficient" diversified portfolios of primary energy sources. This section presents five energy supply indicators for APEC member economies.

- Diversification of Primary Energy Demand (ESI $_{I}$)
- Net Energy Import Dependency [weighted by consumption intensity of Primary Energy Sources (PES)] (ESI $_{II}$)
- Non-Carbon based Fuel Portfolio (ESI $_{III}$)
- Net Oil Import Dependency [weighted by consumption intensity of Oil as a PES] (ESI $_{IV}$)
- Middle East Oil Import Dependency (ESI $_{V}$)

These indicators are applied to the portfolio of sources for primary energy demand and are used to evaluate energy supply projections for 2004 and 2030.[a] A benchmark summary of each APEC economy's Total Primary Energy Demand (TPED) is first presented, followed by import, export, and source specific Primary Energy Demand (PED) projection results for corresponding periods.

[a] Middle East import dependency is evaluated on a historical time scale, rather than making future projections.

METHODOLOGY

TOTAL PRIMARY ENERGY DEMAND

To calculate the security of energy supply within the APEC region, analysis of the region's primary energy was conducted. Total Primary Energy Demand (TPED) considers Coal, Oil, Gas, Hydro, and NRE sources. These source categories are comprised of the following:

- "Coal" - All coals, both primary and derived fuels, and peat;
- "Oil" - Crude oil, natural gas liquids, refinery feedstocks, and additives as well as other hydrocarbons and petroleum products (excluding biofuels for the US);
- "Gas" - Natural gas and town gas;
- "Hydro"- Hydro-electric power
- "NRE" - Biomass, geothermal, wind, solar and other new and renewable energy.

The TPED value is determined by calculating both the indigenous production and the net imports of these sources.[b] In these calculations, net imports are defined as imports minus exports.

[b] Net electricity imports are not considered in the energy projections for primary energy demand

Historical data from 2004 is acquired from the International Energy Agency (IEA) database, and therefore includes statistical differences, stock changes, non-energy consumption and others. As a result of the different methodologies used to aggregate the data, some discrepancy in the trend analysis was observed.

ENERGY SECURITY INDICATORS

The values determined for PED were used to design macro indicators for energy supply security. These indicators were designed to reflect the importance and potential risks, in terms of primary energy sources, associated with energy portfolio decisions. The five macro indicators are reflective of potential risks/ benefits associated with diversification of energy resources and import dependencies.

Energy Security Indicator I (ESI_I), which measures the Diversification of Primary Energy Demand (DoPED) was developed by modifying the Shannon Index, a diversity index used to measure biodiversity. This index was utilised since it considers both the significance of diversification in terms of abundance and equitability of sources. The indicator, adapted from this index is shown below:

$$D = -\sum (p_i \ln p_i)$$

$$ESI_I = DoPED = \frac{D}{D_{MAX}} = \frac{D}{\ln T} \qquad (ESI_I)$$

Where:
ESI_I= Energy supply security indicator 1
D= Shannon's Diversity Index
p_i= share of PES i in TPES
i= 1….T: primary energy source index (T sources are utilised)

The final value acquired from this indicator is normalised on a 0-100 scale. A value close to zero implies that the economy is dependent on one energy source and a result close to 100 implies that the economy's energy sources are evenly distributed among the main energy sources. Thus, a lower ESI_I value reflects a higher risk of energy supply security.

The second indicator, referred to as ESI_{II}, measures an economy's Net Energy Import Dependency (NEID). The Shannon Index was also utilised for this indicator; however it was altered to reflect the impact of both diversification and imports on energy supply security. The NEID of each economy is weighted by the consumption intensity of each primary energy source (PES). The indicator, adapted from this index is shown below:

$$D = -\sum (c_i \, p_i \ln p_i)$$

Subject to: $c_i = 1 - m_i$

$$DoPED_{Import\ Reflective} = \frac{D}{D_{MAX}} = \frac{D}{\ln T}$$

$$ESI_{II} = NEID = 1 - \frac{DoPED_{Import\ Reflective}}{ESI_I} \qquad (ESI_{II})$$

Where:
ESI_{II}= Energy supply security indicator 2
c_i= correction factor for p_i
m_i= share of net import in PES of source i

The final value acquired from this indicator is calculated as a percentage. A value closer to zero implies that the economy relies on domestic sources to meet its PED. A result close to 100% implies that the economy is highly dependent on imports and may possess a limited supply of domestic sources to meet its PED. Thus, a higher ESI_{II} value reflects a higher risk of energy supply security.

The third indicator, referred to as ESI_{III}, measures an economy's efforts to switch away from a carbon intensive fuel portfolio (NCFP). The NCFP of each economy takes into account the share of demand that hydro, nuclear, and NRE contribute to TPED. The indicator is shown below:

$$ESI_{III} = NCFP = \frac{(\text{Hydro PED}) + (\text{Nuclear PED}) + (\text{NRE PED})}{(\text{Total Primary Energy Demand})} \qquad (ESI_{III})$$

The final value acquired from this indicator is calculated as a percentage. A higher ESI_{III} percentage reflects a greater potential offset, in terms of decreasing potential environmental degradation, to an economy's energy supply security.

The fourth indicator, referred to as ESI_{IV}, measures an economy's Net Oil Import Dependency (NOID). The NOID of each economy takes into account oil imports and exports and is weighted by the consumption intensity of Oil as a primary energy source. The indicator is shown below:

$$ESI_{IV} = NOID = \frac{\text{Net Oil Imports}}{(\text{Oil Primary Energy Demand})} \times \frac{(\text{Oil PED})}{(\text{Total PED})} \qquad (ESI_{IV})$$

The final value acquired from this indicator is calculated as a percentage. Similar to ESI_{II}, a higher ESI_{IV} percentage reflects a higher risk of supply security.

The final indicator, referred to as ESI_{V}, measures an economy's Middle East Oil Import Dependency (MEOID). Historical data for this indicator was acquired from Blackwell Publishing's *World Oil Trade: An Annual Analysis and Statistical Review of International Oil Movements*. Blackwell Publishing reported international crude and products trade in thousand barrels per day, which were converted to tons of oil equivalent (toe) based on a worldwide average gravity conversion factor for crude oil. Certain data values were not available for the specified time period. The indicator is shown below:

$$ESI_{V} = MEOID = \frac{\text{Middle East Oil Imports}}{(\text{Oil Primary Energy Demand})} \qquad (ESI_{V})$$

The final value acquired from this indicator is calculated as a percentage.

FINDINGS

TOTAL PRIMARY ENERGY DEMAND

Total primary energy demand through 2030 is projected to increase at a rate of 1.8% per year. This demand will be met primarily by conventional resources such as coal, natural gas, and oil. As a result of this increase in demand and decreasing domestic supplies, many economies will increase their dependence on imported fossil fuels. Concurrently, some of the APEC regions' principal exporters will begin to decrease their exporting potential. This will negatively impact the region's potential to acquire resources internally, as such increasing dependence on other exporting regions in Africa, the Americas, and the Middle East. The following sections provide a brief explanation of the trends within the coal, natural gas, and oil sectors, specifically focusing on the trends for both importers and exporters within each sector.

Total Primary Energy Demand		
2004 (Mtoe)	2030 (Mtoe)	Growth Rate (% per year)
6,505.6	10,332.2	1.8

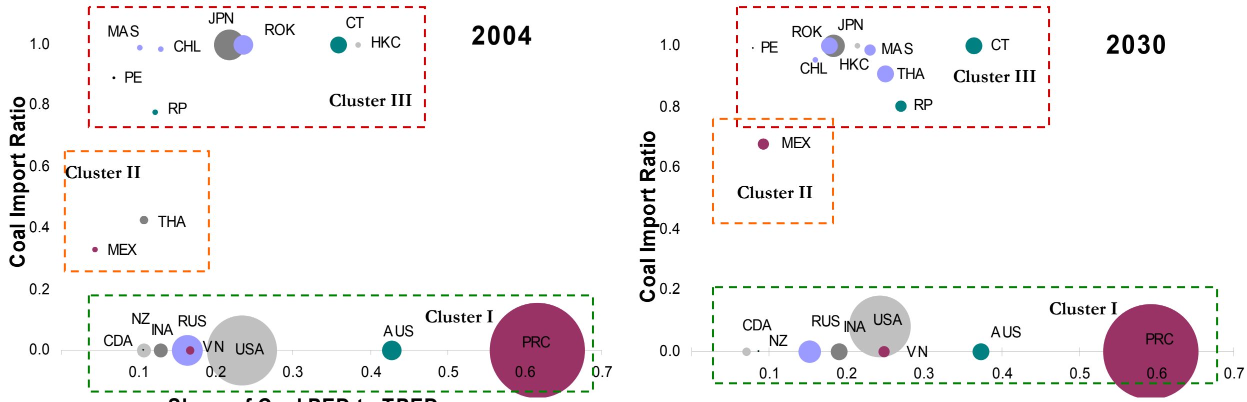
45.1 Total primary energy demand in the APEC region, 2004 and 2030
APERC 2007

COAL PRIMARY ENERGY DEMAND

Coal accounts for the second largest share of total primary energy demand. It is projected to have the fastest annual growth rate, about 2.8%, between now and 2030.[c] In terms of coal consumption, there are

[c] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

three major groupings that categorise the usage patterns and import dependence of the region. Cluster I consists of economies -Australia, Canada, China, Indonesia, New Zealand, Russia, the United States, and Viet Nam- that rely primarily on domestic resources to meet their coal energy demand. These economies import very little coal, under 20% of their supply, to meet their required demand. Cluster I economies tend to use a larger physical quantity of coal than economies without domestic resource supplies [46.1, 46.2]. Cluster II consists of economies transitioning to a higher coal import dependency. These economies import between 30-80% of their coal supply. Cluster III consists of economies -Chinese Taipei, Chile, Japan, Korea, Hong Kong, Malaysia, Peru, and the Philippines- that are highly dependent on imports. These economies import over 80% of their supply. Cluster III economies tend to use a substantially smaller physical quantity of coal than their counterparts in Cluster I.

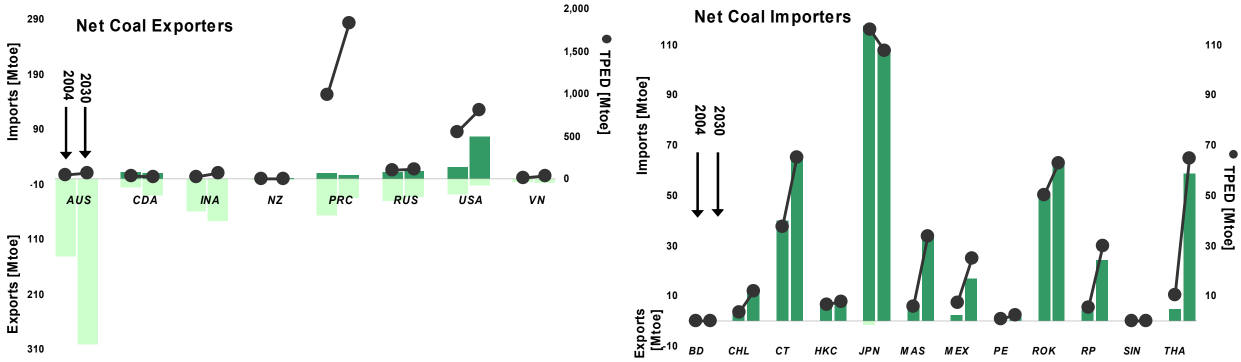


46.1, 46.2 **Coal consumption patterns, 2004 and 2030**
APERC 2007

These charts demonstrate the changes in import dependence and share of coal PED to TPED for 2004 and 2030. The size of the circles emphasises the physical quantity used by the economy versus that of other economies in the region. In both years, China and the United States use the largest physical quantity of coal. Economies with very little coal consumption were excluded from these charts.

Many economies, between 2004 and 2030, remain in the same cluster groupings. The only substantial changes that occur are within Cluster III, where certain economies -the Philippines, Malaysia, and Thailand- increase their share of Coal PED to TPED.

Projections for 2030 reveal that the APEC region will shift its status from being a net exporter of coal to that of a net importer. As for specific country projections, twelve economies are net coal importers in 2004. By 2030, the United States, initially a net exporting economy, is projected to become a net importer.



47.1, 47.2 **Coal imports versus exports, 2004 and 2030**
APERC 2007

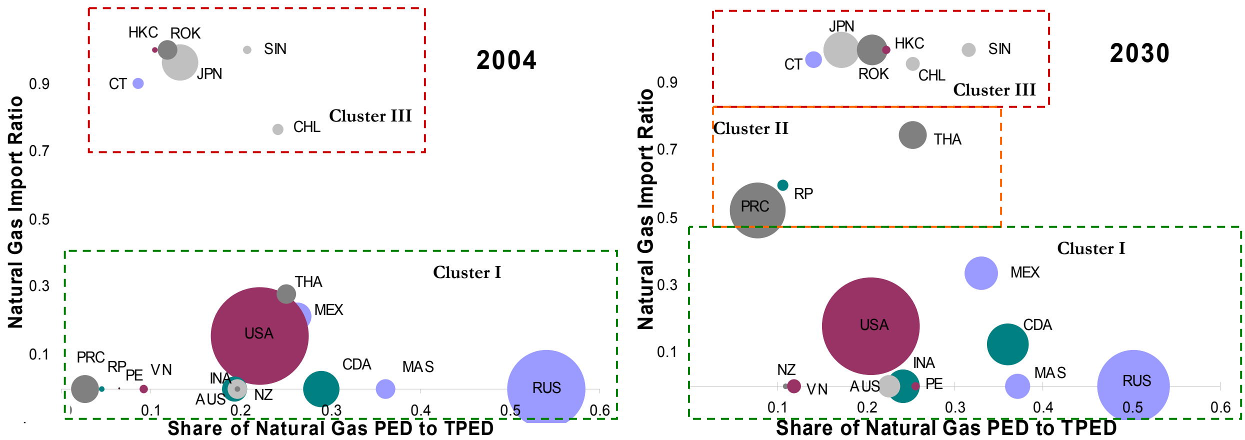
These charts demonstrate the changes in imports, exports, and coal PED between 2004 and 2030.

Most coal exporting economies -New Zealand, China, Russia, the United States, and Viet Nam- are projected to decrease their exports between 2004 and 2030.[d] Off-setting this decline slightly, larger increases in exports are expected from Australia, Canada, and Indonesia. Nevertheless, this increase in exports cannot counter the large increase in imports from other APEC economies.

[d] Economies referenced are exporting economies, not necessarily net exporters.

NATURAL GAS PRIMARY ENERGY DEMAND

Natural gas accounts for the third largest share of total primary energy demand. It is projected to have an annual growth rate of about 1.8%, a bit lower than the average growth rate of total energy demand. In terms of natural gas consumption, there are also three major groupings that categorise the usage patterns and import dependence of the region. Cluster I consists of economies -Australia, Canada, Indonesia, Mexico, Malaysia, New Zealand, Papua New Guinea, Peru, Russia, the United States, and Viet Nam- that rely primarily on domestic resources to meet their natural gas energy demand. These economies import under 30% of their supply to meet their required demand. Cluster I economies tend to use a larger physical quantity of natural gas than economies without domestic resource supplies [47.3, 47.4].

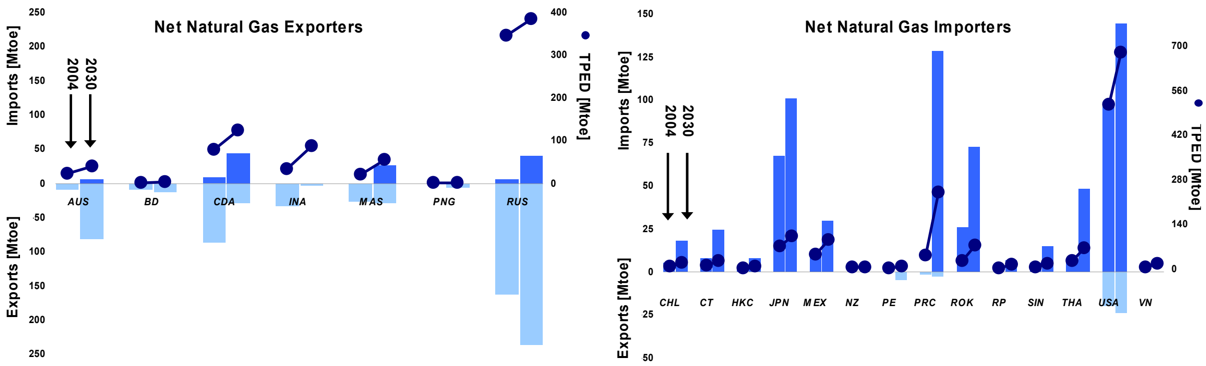


47.3, 47.4 **Natural gas consumption patterns, 2004 and 2030**
APERC 2007

These charts demonstrate the changes in import dependence and share of natural gas PED to TPED for 2004 and 2030. The size of the circles emphasises the physical quantity used by the economy versus that of other economies in the region. In both years, Russia and the United States use the largest physical quantity of natural gas. Economies with very little natural gas consumption were excluded from these charts.

Cluster II consists of economies -China, the Philippines, and Thailand- that are transitioning to a higher coal import dependency. These economies are projected to import between 30-80% of their natural gas supply by 2030. In 2004, these Cluster II economies were less dependent on imported resources; however, this is projected to change as a result of decreasing domestic production rates. Cluster III consists of economies -Chinese Taipei, Chile, Japan, Korea, Hong Kong, and Singapore- that are highly dependent on imports. These economies import over 80% of their supply. Natural gas Cluster III economies, similar to those in coal Cluster III, use less natural gas than their counterparts in Cluster I.

Natural gas projections follow similar trends to those of coal. It is projected that the APEC region will become a net importer of natural gas by 2015. As for specific country projections, fourteen economies are net natural gas importers in 2004. In terms of natural gas exporters, it is projected that Canada and Indonesia will decrease their exports between 2004 and 2030.



48.1, 48.2 **Natural gas imports versus exports, 2004 and 2030**

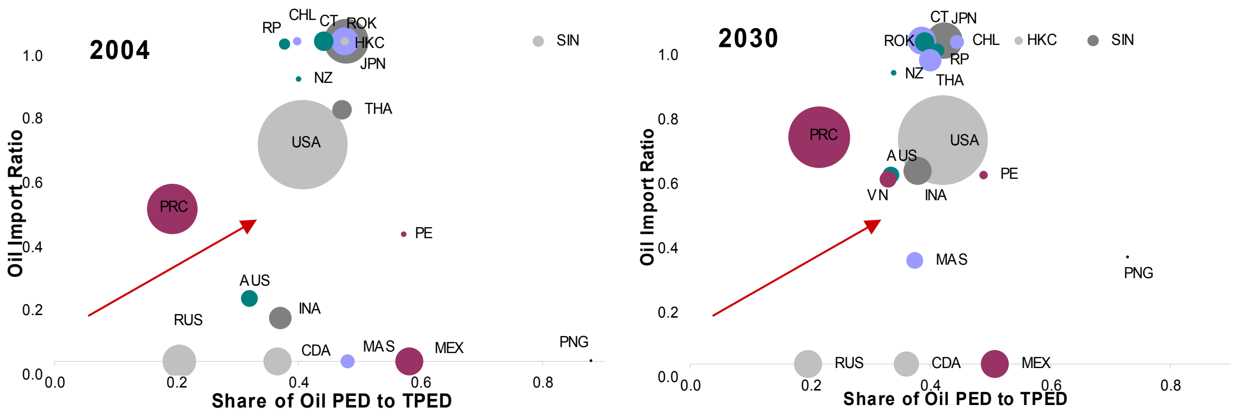
APERC 2007

These charts demonstrate the changes in imports, exports, and natural gas PED between 2004 and 2030.

A few economies -Australia, Brunei Drassalum, Malaysia, Peru, Russia, and the United States- are projected to increase their natural gas exports by 2030. The most significant natural gas exports will come from Russia (237 Mtoe) and Australia (81 Mtoe).

OIL PRIMARY ENERGY DEMAND

Oil accounts for the largest share of total primary energy demand for the APEC region. Forecasts predict that it will continue to dominate demand, while continuing to grow at an annual growth rate of about 1.7%, between now and 2030. In terms of economy specific use, a high oil import dependency is more significant since it contributes a larger portion to TPED. The consumption patterns within the APEC region, considering the share of oil to TPED and import ratios, are more analogous than the other primary sources.

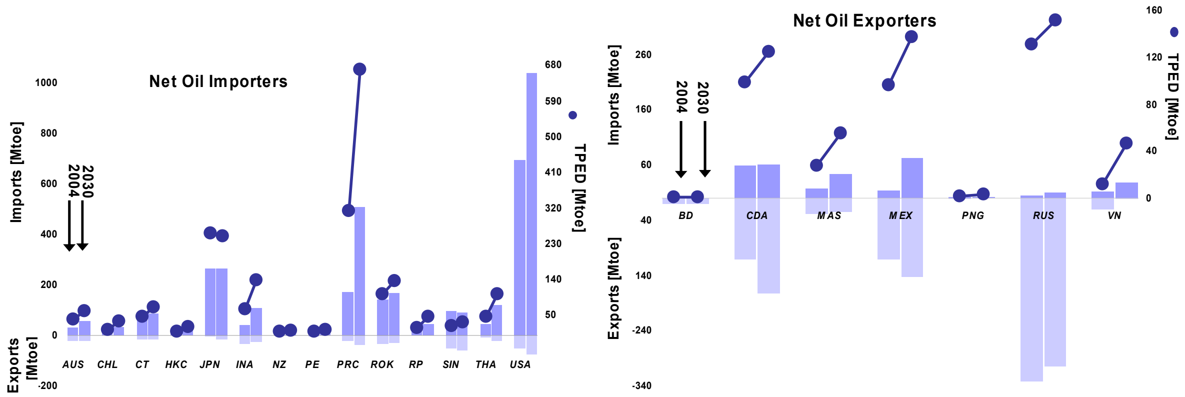


49.1, 49.2 **Oil consumption patterns, 2004 and 2030**
APERC 2007

These charts demonstrate the changes in import dependence and share of oil PED to TPED for 2004 and 2030. The size of the circles emphasises the physical quantity used by the economy versus that of other economies in the region. In both years, China, Japan, and the United States use the largest physical quantity of oil. Economies with very little oil consumption were excluded from these charts.

Forecasts predict that the trend in oil consumption within the APEC region is approaching the upper levels of resource dependency, since economies are expected to increase their share of oil as a primary resource, while increasing their dependence on imports to meet this additional demand. This trend is more pronounced in the oil sector than in the other resources.

In terms of imports versus exports, fourteen economies were net oil importers in 2004. Projections for 2030 reveal that three current net exporting economies -Malaysia, Papua New Guinea, and Viet Nam- will become net importers.



49.3, 49.4 **Oil imports versus exports, 2004 and 2030**
APERC 2007

These charts demonstrate the changes in imports, exports, and oil PED between 2004 and 2030.

However, a few net importing –China, Singapore, Thailand, and the United States- and net exporting –Canada and Mexico- economies are projected to increase their oil exports by 2030. Forecasts show that the most significant oil exports will come from Russia (304 Mtoe), followed by Canada (172 Mtoe).

ENERGY SECURITY INDICATORS

The following section provides a brief explanation of the general trends associated with the five energy security indicators that were previously discussed. The values obtained by these calculations are shown below:

ENERGY SECURITY INDICATOR I

As previously discussed, ESI_I measures the level of diversification within APEC economy's primary energy demand. The ESI_I values displayed in [50.1] are normalised on a 0-100 scale, where a result close to 100 implies that the economy's energy sources are evenly distributed among the main energy sources. In 2004, most economies had an ESI_I value ranging from the low 60's to mid 80's. These values suggest that economies are moderately diversifying their demand portfolios; however, most of these economies are still primarily dependent on 1-2 sources for their entire demand. Economies with values lower than 50, are primarily dependent on one source of energy to meet their demand. This lower ESI_I value reveals that the economy has a higher level of energy supply security risk because they are more susceptible to any changes occurring in the variable energy markets surrounding this source.

ESI_I	2004	2030
AUS	69	71
CDA	87	83
JPN	76	80
ROK	72	82
MEX	63	65
NZ	83	78
USA	79	79
BD	35	35
CHL	81	76
PNG	25	48
PRC	61	68
CT	70	74
HKC	54	56
INA	75	76
MAS	64	66
PE	69	74
RP	67	74
RUS	70	76
SIN	29	39
THA	71	72
VN	74	90

50.1 Diversification of primary energy demand, 2004 and 2030

APERC 2007

For the most part, demand projections for 2030 reveal that economies will continue to diversify their demand portfolios. However, the forecasts also display a decrease in diversification for some economies -Canada, Chile, and New Zealand.[e] These projections reveal that in terms of average APEC diversification efforts, a common area of stability seems to be attained within the mid 70's to mid 80's range. There are a few economies that will remain very low in terms of diversification; however, those that exhibit high import tendencies also exhibit great strides towards diversification of their demand portfolios.

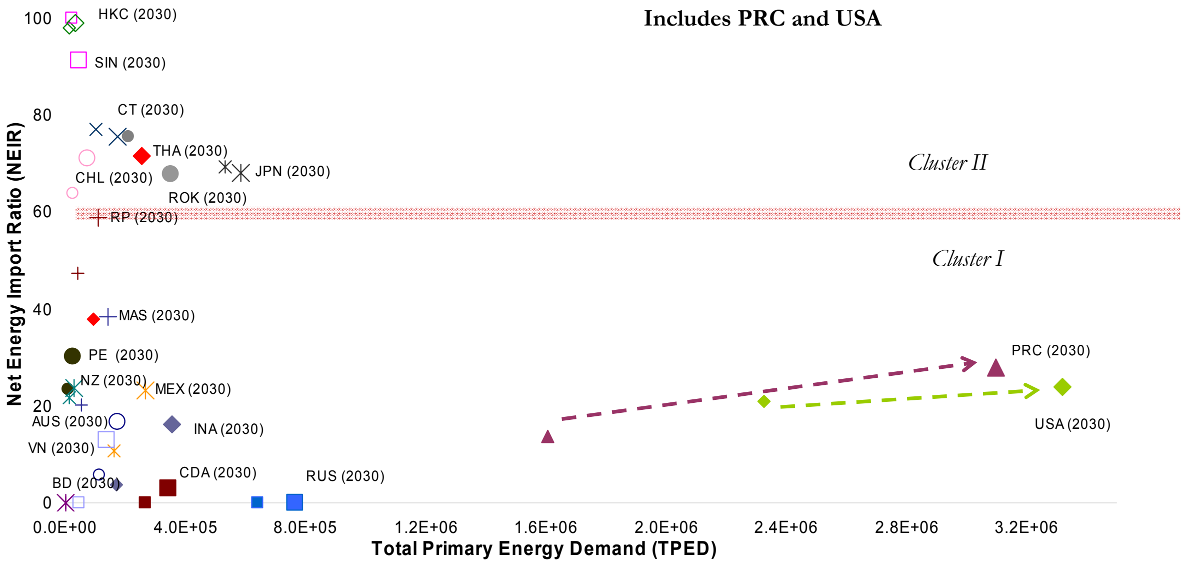
[e] The underlying reason for these decreases are: (1) the rising share of natural gas and oil at the expense of coal and nuclear in Canada and (2) the rising share of renewable energy at the expense of natural gas in New Zealand.

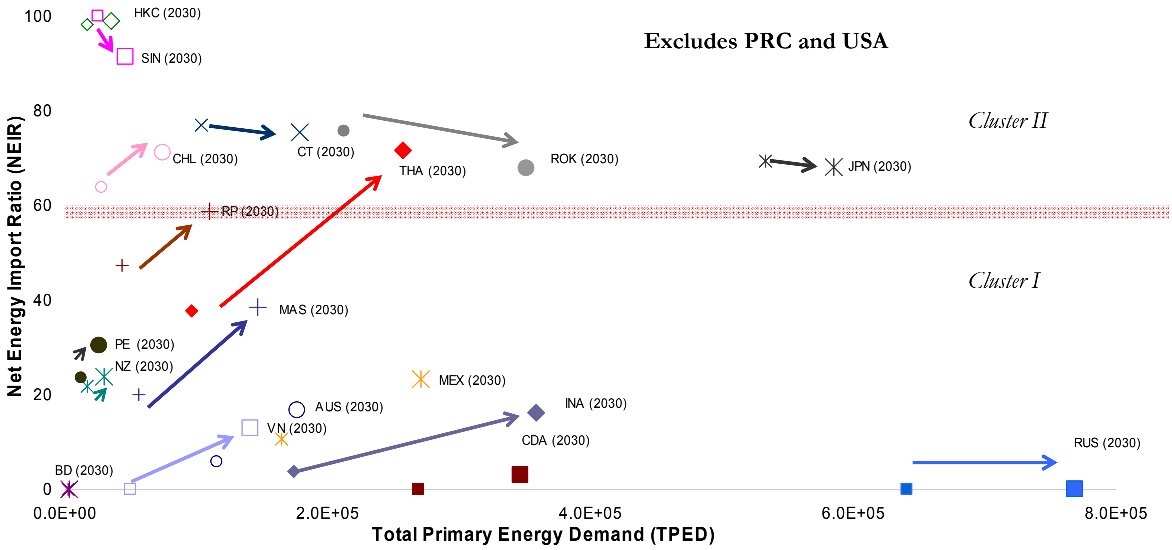
Overall, this indicator reveals the potential for decreasing the energy supply risk within an economy. If an economy is solely dependent on one source of energy, any import dependency can prove detrimental because of the variability in the current and future energy source trade market. The effect of import dependencies on demand portfolios will be discussed within ESI_{II}.

ENERGY SECURITY INDICATOR II

ESI_{II} indicates the level of total primary supply import dependency, which is weighted by the consumption intensity of each resource. ESI_{II} values reveal the presence of two major cluster groupings that categorise the net import dependency of the region. Cluster I consists of economies that rely primarily on domestic resources to meet their primary energy demand.[f] In 2004, these economies imported under 60% of their supply to meet their required demand. Demand forecasts for 2030 reveal that Cluster I economies will not only increase their TPED, but they are also expected to increase their net import dependency during this time period [51.1, 51.2].

[f] Chile and the Philippines are included in this group because they are projected to have a similar import dependency trend as economies with lower NEIR values.





51.1, 51.2 Net energy import ratio vs. total primary energy demand, 2004 and 2030
APERC 2007

The charts above demonstrate the changes in NEIR and TPED for 2004 and 2030 for all of the economies in the APEC region. The arrows display the changes over time. The first chart specifically points out China and the United States, the most energy intensive economies within the region. The second chart highlights the changes between economies with a lower TPED. The red line separates the two major groupings that characterise import trends within the region.

Cluster II consists of economies that rely primarily on imported resources, over 60 %, to meet their primary energy demand. Demand forecasts for 2030 reveal that Cluster II economies will also increase their TPED; however, these economies are expected to decrease their net import dependency during this time period.[g]

[g] Not all economies that fall within a particular cluster show similar characteristics. For example, Chile exhibits many of the characteristics of Cluster I economies.

The ESI_{II} projections are significant because they reflect the importance of source diversification on import dependency. Table [52.1] displays two different values for ESI_{II}, one where the value is weighted by the economy's source diversification in terms of abundance and equitability of sources, and the other where all sources are considered equal in their contribution to TPED.

	ESI_{II} (weighted)		ESI_{II} (non-weighted)	
	2004	2030	2004	2030
AUS	5.7	16.7	0	0
CDA	0.0	3.1	0	0
JPN	69.3	68.1	99	100
ROK	75.6	67.8	99	100
MEX	10.6	23.3	0	0
NZ	21.7	23.8	41	66
USA	21.0	23.9	35	54
BD	0.0	0.0	0	0
CHL	63.9	71.1	91	98
PRC	13.8	27.8	7	64
CT	77.0	75.5	99	100
HKC	98.1	99.0	100	100
INA	3.8	16.1	0	0
MAS	20.1	38.4	0	33
PE	23.5	30.3	41	22
RP	47.3	58.8	87	93
RUS	0.0	0.0	0	0
SIN	100.0	91.3	100	100
THA	37.8	71.6	58	90
VN	0.0	13.0	0	35

52.1 Net Import Dependency (weighted by source diversification) vs (non-weighted) 2004 and 2030
APERC 2007

Analysis of the indicator's results reveals that diversification can significantly impact, for better or worse, an economy's import dependence. The degree of net import dependency is waned when an economy has a high diversification of supply. Consequently, low diversification ratios will adversely impact import dependence. These results expose potential options for economies that have decreasing domestic resources to increase their supply security. Energy supply security can be augmented by increasing the abundance and equitability amongst the energy sources that contribute to TPED.

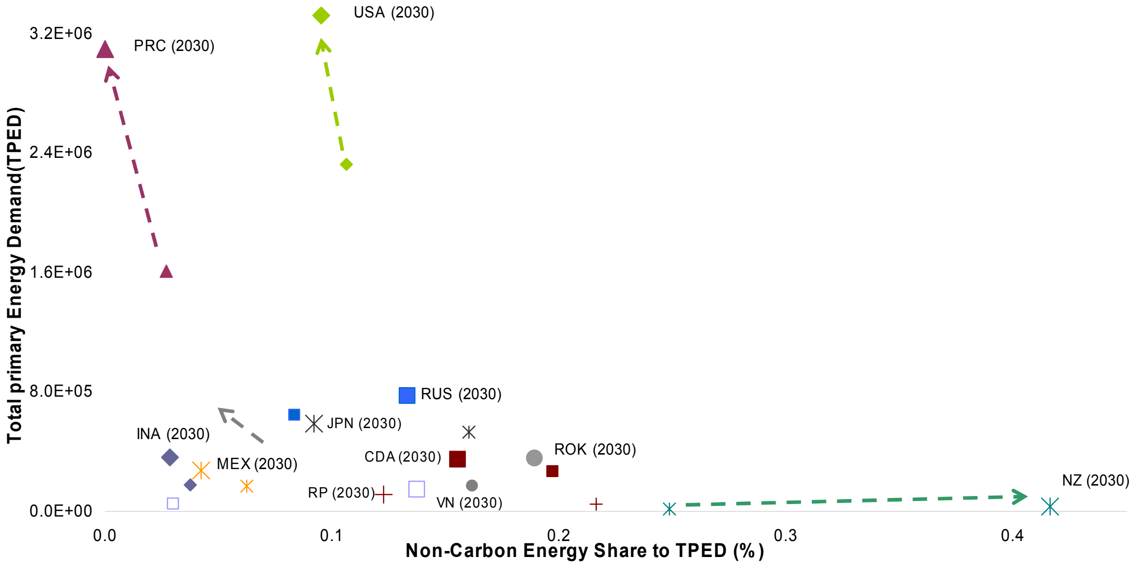
ENERGY SECURITY INDICATOR III

Concern over the acceptability of sources used to meet demand, specifically in terms of greenhouse gas emissions, has increased over the past few decades. As a result, the potential for fuel switching towards a less carbon-intensive fuel portfolio has grown in public appeal. ESI_{III} tries to quantify each economy's progress in diversifying towards alternative fuel sources by increasing the share of renewables/ non-fossil fuels used to meet their demand needs.

ESI_{III} values reveal that most economies are either remaining constant (7 out 21 economies) or decreasing (9 out of 21 economies) their share -relative to their growth in consumption- of non-carbon fuels to meet TPED. Although many economies are increasing the total quantity of energy supplied by non-carbon based fuels, this is not increasing at the same rate as their total primary demand growth. As a result, the indicator shows a decreasing trend over time.

	ESI_{III}	
	2004	2030
AUS	0.01	0.01
CDA	0.20	0.16
JPN	0.16	0.09
ROK	0.16	0.19
MEX	0.06	0.04
NZ	0.25	0.42
USA	0.11	0.10
BD	0.00	0.00
CHL	0.07	0.07
PNG	0.05	0.15
PRC	0.03	0.00
CT	0.10	0.10
HKC	0.00	0.00
INA	0.04	0.03
MAS	0.01	0.01
PE	0.12	0.09
RP	0.22	0.12
RUS	0.08	0.13
SIN	0.00	0.00
THA	0.01	0.00
VN	0.03	0.14

52.2 Non-carbon fuel portfolio, 2004 and 2030
APERC 2007



53.1 **Non-carbon fuel portfolio vs. total primary energy demand, 2004 and 2030**

APERC 2007

Certain economies were not included in this chart because they showed little change between the two time periods.

In lieu of these trends, this indicator reveals the importance of future carbon sequestration technology development. Non carbon-based fuel sources are not growing at a fast enough rate to offset future primary demand growth and the increase in greenhouse gas emissions that will be associated with this growth. If these trends continue, this indicator reveals that most economies will need to focus their efforts on potential carbon sequestration technologies to meet future Kyoto Protocol targets on carbon emissions reductions.

ENERGY SECURITY INDICATOR IV & V

Since oil is expected to remain the primary energy source within the APEC region, oil supply acquisition is a major concern for energy security. ESI_{IV} and ESI_{V} both aim at quantifying the potential risks associated with the attainment of this resource. ESI_{IV} projections, which are weighted by the share of oil to TPED, reveal that 10 APEC member economies -Australia, Chile, China, Indonesia, Malaysia, Peru, Thailand, the United States, and Viet Nam-- will increase their net oil import dependence by 2030. Economies that reveal a decrease in their ESI_{III} assessment -Korea, New Zealand, Chinese Taipei, Hong Kong, and Singapore- decreased the share that oil contributed to their TPED. As such, this once again reflects the importance of diversification in determining efficient portfolios of primary energy sources.

The values acquired from ESI_{IV} reveal that oil imports will considerably increase in the future. However, as discussed in the oil primary demand section, oil exporting economies within the APEC region are decreasing. As such, other regions will be solicited to provide additional import capacity. ESI_{IV} evaluates the extent to which the Middle East historically has supplied oil resources to the APEC region, as a means to interpret its potential contributions in the future.

ESI_{IV}		
	2004	2030
AUS	6.2	19.5
CDA	0.0	0.0
JPN	48.2	42.3
ROK	50.6	38.6
MEX	0.0	0.0
NZ	35.1	30.5
USA	27.6	29.1
BD	0.0	0.0
CHL	43.8	44.4
PRC	9.2	15.2
CT	46.3	38.9
HKC	47.5	54.7
INA	5.1	22.7
MAS	0.0	12.0
PE	22.8	28.4
RP	37.3	40.1
RUS	0.0	0.0
SIN	79.3	67.0
THA	37.0	37.5
VN	0.0	18.8

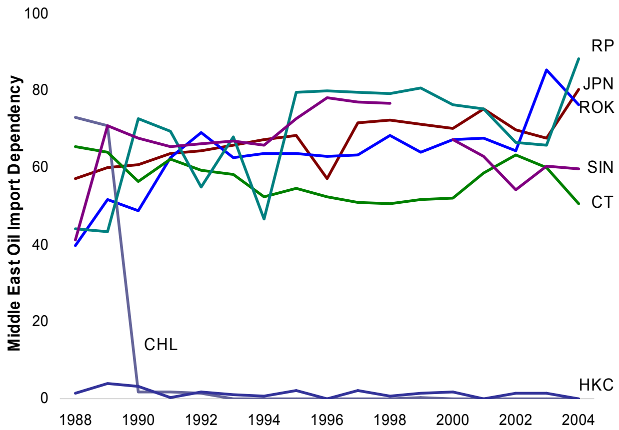
53.2 **Net oil import dependence, 2004 and 2030**

APERC 2007

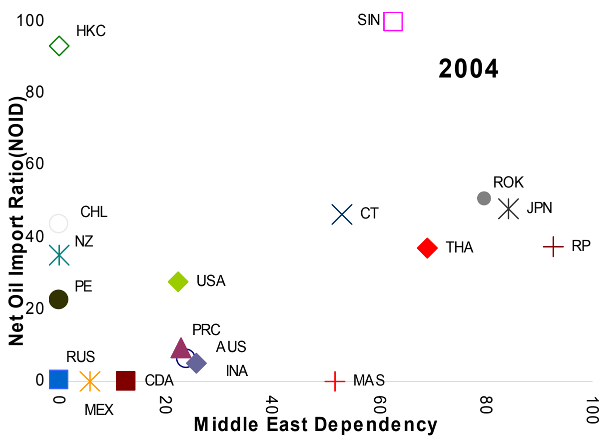
ESIv																	
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
AUS	50.5	51.8	48.6	43.7	42.0	62.8	41.4	40.1	34.5	33.8	25.3	20.6	29.4	21.9	16.7	16.9	22.9
BD	0.0	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	--	--	--	--
CDA	4.7	9.5	11.5	12.3	13.3	18.0	11.7	9.7	11.0	13.5	9.8	7.6	10.0	11.8	13.7	12.3	12.1
CHL	73.2	70.9	1.9	1.8	1.4	--	--	--	--	0.0	0.0	0.4	--	0.0	--	--	0.0
CT	65.6	64.3	56.7	62.2	59.4	58.2	52.4	54.8	52.4	51.1	50.8	51.9	52.3	58.9	63.5	60.0	50.7
HKC	1.6	4.1	3.4	0.3	1.8	1.1	0.8	2.0	--	2.3	0.8	1.4	1.7	0.0	1.4	1.6	0.0
INA	57.0	70.5	61.5	57.4	49.0	38.1	50.6	38.3	38.5	32.6	--	--	43.6	33.7	28.1	30.7	24.7
JPN	57.1	60.3	61.0	63.9	64.6	66.1	67.3	68.5	57.2	71.8	72.6	71.5	70.4	75.4	70.0	67.6	80.4
MAS	22.8	19.9	0.0	0.0	18.3	22.4	18.8	25.1	20.9	17.4	18.3	31.9	44.9	46.9	30.0	39.6	49.4
MEX	0.0	0.0	0.0	0.0	--	--	0.0	0.0	0.0	0.0	2.5	4.2	3.4	4.0	4.4	6.0	5.6
NZ	62.3	65.9	70.9	73.8	70.8	70.4	60.8	--	--	--	--	--	--	--	--	--	--
PE	0.0	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	--	--	--	--
PNG	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PRC	0.0	0.0	18.5	26.8	14.7	22.0	18.9	22.8	28.9	26.2	30.5	28.0	40.3	38.8	35.5	30.6	21.8
ROK	40.0	51.7	48.9	62.5	69.2	62.5	63.9	63.8	63.2	63.3	68.5	64.3	67.5	67.6	64.6	85.4	76.3
RP	44.3	43.4	72.8	69.6	55.1	68.2	46.8	79.6	80.1	79.7	79.3	80.8	76.3	75.4	66.7	66.0	88.6
RUS	--	--	--	--	--	--	32.3	--	0.2	--	--	--	--	--	--	--	0.0
SIN	41.3	71.0	67.6	65.4	66.4	67.1	65.9	72.8	78.4	77.3	76.8		67.3	63.0	54.4	60.6	59.9
THA	15.1	38.1	19.4	34.6	34.3	38.5	38.6	46.5	41.6	68.1	--	70.4	73.9	76.5	68.6	66.6	65.8
USA	21.5	22.8	25.2	23.6	22.7	20.8	19.7	17.6	14.8	16.5	18.4	20.6	19.8	22.0	18.9	3.2	21.3
VN	--	--	--	--	--	--	--	--	--	--	--	0.0	0.0	--	--	--	--

54.1 **Middle East oil dependency, 1988-2004**
APERC 2007

Historical trends show a slight increase, 0.2% per year (0.6% for the top 7 net oil importers), in Middle East oil dependency over the past two decades. As of 2004, seven APEC economies – Chinese Taipei, Japan, Korea, Malaysia, Philippines, Singapore, and Thailand- relied over 50% on the Middle East to supply their imported oil requirements. In the future, this trend is expected to increase substantially, as economies increase their oil import dependencies. Although future projections on this dependence are limited, the growth in oil demand, coupled with the decrease in APEC oil exports, signals a continued growth in imports from both the Middle East and Africa.



54.2 **Middle East oil dependency trends (Top 7 net oil importers), 1988-2004**
APERC 2007



54.3 **Middle East oil dependency, 2004**
APERC 2007

CASE STUDY: OIL SUPPLY SECURITY

INTRODUCTION

Oil is the cornerstone of the APEC region's current (about 34%) and future primary energy demand. As discussed in previous chapters, forecasts predict that oil consumption will continue to grow, between 2004 and 2030, at an annual rate of 1.7%. This growth in demand, coupled with growing resource constraints and the risk of high oil prices, accentuates the importance of oil supply security in the short and long term prospects for the region.

As a means to further understand the impact of oil supply security within the APEC region, primarily focusing on the risk factors and potential offsets, two oil supply indicators were created. The first indicator, Oil Supply Risk, primarily focuses on capturing the importance of potential risks that can decrease an economy's oil supply security. The second indicator, Oil Supply Offset, incorporates different options that can help reduce an economy's risk to growing oil dependence and the risks with accessing additional supply to meet this demand.

A historical analysis of oil supply security was conducted for ten APEC economies. These economies include: Australia, Canada, China, Indonesia, Indonesia, Japan, Korea, Mexico, Russia, Thailand, and the United States. These economies were chosen specifically because they represent the highest levels of total primary oil demand for the region. Additionally, these economies reflect the geographical diversity within the region, since at least one economy is included from Oceania, North America, Northeast Asia, and South East Asia.

An analysis of these economies' oil supply security was conducted to determine the factors that most greatly impact security of supply at different levels of demand growth, import dependency, and economic development. These indicators were determined for 2004, since it is the most recent year for which all of the factor analysis could be conducted. In addition, analysis was conducted for 1996, as a mid point between the Mexican and Asian Economic Crisis, in order to view the impact that economic development may have on oil supply risk.

Ultimately, these indicators were created as a tool to gauge both economies' vulnerabilities to fluctuations in oil supply and potential options that can help reduce the risk of these vulnerabilities during periods of varying oil prices. As a result, these economies are ranked based on their supply risk and offset potential. This serves as a comparative facilitator, so that each economy can gauge their comparative position between others at different levels of demand growth and import dependency. This may help provide insight into future security trends, as different economies follow similar patterns of development or oil demand growth.

METHODOLOGY

OIL SUPPLY RISK INDICATOR

The oil supply risk indicator was designed to identify the fundamental driving factors that contribute to decreasing an economy's oil supply security, as it relates to meeting its primary energy demand. Although many factors can play a role in increasing risk, five variables reflective of a range of both demand and supply dynamics were included. To calculate the final indicator, each variable was given a different weighted value, so as to represent its relative influence on current supply risk. Over time, the weight of each variable will vary since changes in government policy can sway the influence of any given variable. The variables included and their respective weights are as follows: per capita oil consumption (30%), oil demand elasticity (25%), economic risk of imports (25%), political stability risk of imports (10%), and refining infrastructure capacity (10%). The data used for this indicator was collected from the International Energy Agency (IEA), the World Bank, Blackwell Publishing, and other official government sources.

A brief discussion of each variable is included below:

An economy's per capita oil consumption is currently the most critical driver that impacts oil supply security. This variable provides an essential foundation for determining the degree of supply risk, since a higher demand requires additional acquisition of resources. This is especially important within the APEC region, since most economies are net oil importers. As a result of decreasing APEC oil reserves, a great deal of the demand will have to be supplied by outside regions, such as Africa, the Americas, and the Middle East.

This variable is also used for cross-country comparison to determine the magnitude of oil supply, relative to other APEC economies, that each economy will need to acquire in order to meet its demand. Since this variable is the key to determining the actual magnitude of risk, it is given precedence over the other risks that are dependent on total demand for oil.

Oil demand elasticity (GDP/toe) is a proxy to reflect the economic impact that an economy will experience in the event of an oil shortage. If an economy's demand is relatively elastic, it is easier for them to substitute away from oil during periods of high oil price. As such, they are less vulnerable to the variability within the oil market. For economies that experience a very inelastic demand, oil is considered an essential good that is not easily substituted. As such, they are increasingly vulnerable to market changes including price hikes and shortages of supply. As demand becomes more inelastic, an economy becomes more susceptible to oil supply risk. This is particularly the case in industry-heavy economies.

Economic risk of imports is an essential factor that measures the risk associated with acquiring foreign oil supply to meet demand. The degree of risk associated with acquiring oil imports is highly dependant on an economy's purchasing power. To allow comparison between economies with different income levels, and how this would impact supply access, net oil imports (imports minus exports) are normalised by income in this analysis. As discussed in previous chapters, 14 out of 21 APEC economies are net oil importers, since they lack sufficient domestic resources to meet demand. As such, the economic risk of an economy's import dependency is important to include in this factor analysis since it provides a clear indication of financial impediments to supply acquisition. A small value represents a lower risk since the economy has sufficient purchasing power to leverage in negotiations to acquire its required import quota.

Political stability risks associated with oil imports is another critical factor affecting oil supply security. It is important to include this indicator in this analysis since the political stability within oil exporting economies can significantly facilitate or impede access to oil supplies. Violence or lack of governance within exporting oil countries can ultimately hinder the acquisition of resources or create additional time and financial burden in the acquisition process.

The proxy used for this variable was developed by modifying the World Bank's political stability and absence of violence indicator, one of a set of six worldwide governance indicators. Blackwell Publishing's *World Oil Trade: An Annual Analysis and Statistical Review of International Oil Movements* was used to determine the top three oil exporters for each economy. The political stability for each of these three economies was averaged and then multiplied by the ratio of imports to total primary oil demand. The resulting value became the final political stability risk of imports variable.

Refining infrastructure capacity, although ranked lower in risk than some of the other variables, it is still a critical factor in determining oil supply security since many economies are equally reliant, in terms of absolute share towards total oil demand, on oil products. This indicator considers the risk associated with infrastructure capacity deficit and how this can be counterbalanced by an economy's purchasing power. Essentially, an income normalised oil product import dependence is used in this analysis.

This variable indicates that a lack in domestic refining capacity adds an additional level of risk because economies are susceptible to further externalities resulting from an additional level of detachment from resource accessibility. However, similar to the economic risk of imports variable, an economy's purchasing power can help decrease the magnitude of this risk.

OIL SUPPLY OFFSET INDICATOR

The oil supply offset indicator was designed to identify the fundamental driving factors that contribute to offsetting an economy's risk in acquiring enough resources to meet its primary energy demand. In this indicator, four different variables were included. Similar to the previous indicator, each variable incorporated in this offset indicator was given a different weighted value. The variables included and their respective weights are as follows: domestic resource capacity (40%), non-energy intensive industry structure (30%), emergency oil stocks (government +commercial reserves) (20%), and non-carbon based fuel portfolio (10%). The data used for this indicator was collected from the International Energy Agency (IEA) and other official government sources.

A brief discussion of each variable is included below:

Domestic resource capacity is a critical factor that can offset an economy's import demand for resources. This variable takes into account the aggregate level of energy production that contributes to total primary energy demand. Evidently, oil supply risk is minimal if an economy has sufficient domestic resources to meet its demand. However, the availability of any domestic resources can also help reduce the level of oil supply risk. If an economy is rich in indigenous resources (fossil fuels, nuclear, renewables), it has a higher security of supply because it has the potential to fuel switch between sources to meet its demand.

However, regardless of domestic resource capacity, it must be acknowledged that there are constraints that limit the scope of fuel substitution as an emergency measure, especially in the short tem. For example, there is limited switching capability in the transportation sector. Furthermore, many economies have already become less oil intensive in certain sectors, specifically the industrial and power generation sectors. As a consequence, the potential for fuel switching might be diminished for many economies.

Non-energy intensive industry structure is an important indicator that gauges an economy's shift away from an oil-dominated economic structure. As economies move towards a service based structure, their demand on oil decreases since the service sector's demand is dominated by electricity. As this indicator becomes larger, the oil intensity of an economy decreases, as such offsetting potential risks and reducing an economy's vulnerability to changes in oil markets.

Emergency oil stocks, which may include both strategic petroleum reserves (SPR) and commercial stocks, is a critical factor that can offset the risk of short term oil supply disruptions. The existence of oil stockpiles, and the potential to stock draw from secure reserves, can effectively maintain short-term market order within oil importing economies. Since oil stocks are visible and transparent, they have the potential to affect market perceptions, as such serving as a deterrent to politically or economically motivated supply disruptions and offsetting short-term supply risks.

The existence of a non-carbon based fuel portfolio is an important driver to offset physical supply risks and reduce environmental issues concerning the increase of greenhouse emissions. This can help with supply security, since most non-carbon based fuels would be domestically produced, in addition to increasing an economy's potential to meet Kyoto Protocol emission reduction targets. There are certain technological and economical restraints that are currently impeding an increase in this variable's offset potential.

FINDINGS

As previously discussed, the values acquired from the above two indicators were used to create a numerical ranking, in terms of risk and offset potential. These results are ranked in descending order, with (1) representing the economy with the highest risk or oil supply offset.

Oil Supply Risk Indicator

Rank		Oil Consumption (MEX=10)	Economic Risk of Imports	Political Risk of Imports (INA=10)	Oil Demand Elasticity (RUS=10)	Refining Capacity (Deficit)	Score
1	USA	34.9	17.6	8.6	6.2	1.5	**3.5**
2	ROK	22.8	5.6	12.1	21.7	0.0	**3.0**
3	JPN	21.6	9.6	11.3	9.1	6.9	**2.6**
4	PRC	2.6	27.4	3.9	11.2	18.4	**2.5**
5	INA	3.2	2.7	10.0	17.7	54.7	**2.5**
6	CDA	33.3	0.0	8.7	5.9	0.0	**2.5**
7	THA	7.8	4.8	13.8	22.6	0.0	**2.1**
8	AUS	19.8	0.2	11.6	6.5	3.8	**1.8**
9	MEX	10.0	0.0	1.3	10.9	10.3	**1.4**
10	RUS	9.8	0.0	0.6	10.0	0.0	**1.1**

Oil Supply Offset Indicator

Rank		Domestic Resource Capacity	Non-Energy Intensive Industry Structure	SPR	Non-carbon Fuel Switching	Score
1	RUS	97.5	60.0	0.0	8.3	**14.5**
2	MEX	86.2	70.0	0.0	6.2	**14.0**
3	AUS	77.7	71.0	15.3	1.3	**13.9**
4	USA	66.3	77.0	23.7	10.6	**13.9**
5	CDA	68.6	66.2	17.8	19.7	**13.2**
6	PRC	89.9	41.0	0.0	2.7	**12.1**
7	INA	76.5	41.0	4.5	3.8	**11.0**
8	JPN	17.0	68.0	30.4	16.0	**8.7**
9	THA	43.0	46.0	4.4	0.5	**8.0**
10	ROK	2.8	56.0	22.4	16.2	**6.0**

58.1, 58.2 **Oil supply security indicators, 2004**

APERC 2007

In interpreting the results from these indicators, there are a number of caveats that should be noted. In terms of the oil supply risk indicator, it must be reiterated that the findings of this analysis are relative to an economy's economic level. The final scores of two of the five variables -economic risk of imports and refining capacity deficit- were normalised by income. This was done to facilitate comparison between cities with different economic levels. Consequently, certain economies have elevated risk values for these two variables. For example, both Japan and Indonesia have the same absolute level of infrastructure capacity deficit. However, in the final variable calculation, Indonesia has a higher refining capacity risk -by a factor of 8- than Japan.

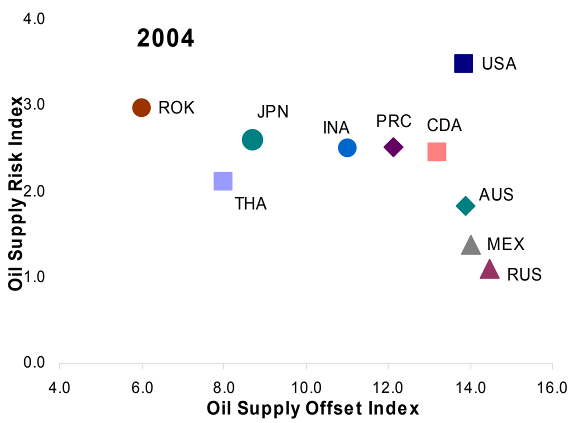
The income normalisation, in this particular case, captures an economy's ability to acquire additional petroleum products on the market and their ability to finance additional refining infrastructure (purchasing power strength can greatly affect an economy's future security of supply). Since these numbers are relative to an economy's current economic level, these variables are highly fluid and can change drastically as a result of economic development. As such, it is important that this is taken into account while interpreting these numbers.

In terms of the oil supply offset indicator, it is important to note that a high offset does not necessarily denote that the economy is less reliant on oil to meet their primary demand. Rather, it signifies that the economy has the highest potential to counteract the effects of oil supply disruptions, possibly through alternative fuel options, amongst the ten economies analysed.

Bearing in mind these few caveats, there are several interesting observations that can be drawn from these calculation results.

In determining the oil supply risk indicator, oil consumption (toe/capita) is the key factor that determines an economy's oil supply risk. In contrast to the lower risk ranking, the top three risk ranking economies have the highest oil consumption rates. Canada, an exception to the above, is an interesting case because although it has a high consumption rate, it is also a net exporter of oil. As such, it is less subject to the other risk factors that burden other high oil consuming economies.

For the oil supply offset indicator, a high domestic resource capacity coupled with a move towards a greater non-energy intensive industry structure tends to have the highest offset potential. These two factors seem to work hand-in-hand and have the greatest offset potential if they are both high. Whereas, solely having a high level of either one diminishes the extent of the offset. This is particularly the case for China and Japan. In China's case, it has a higher domestic resource capacity; however it is still significantly dependant on the industrial sector -46% of its GDP-, as such increasing its demand for oil. Alternatively, Japan has the highest service-based industry structure, but it has barely any indigenous resources, so it is greatly impacted by any change in the oil market.



59.1 Oil supply security indicators, 2004

APERC 2007

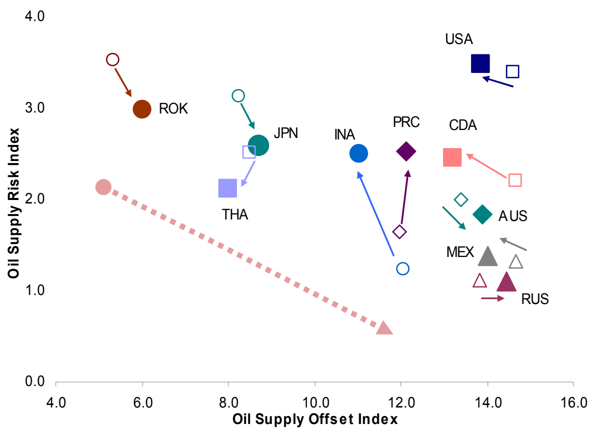
Additionally, it is interesting to note that the economies with the highest oil supply offset have the lowest oil supply risk. The top two offset ranking economies –Russia and Mexico- are net oil exporters, which helps substantiate their ranking on these lists.

Another important observation is associated with the top three ranking supply risk economies –the United States, Korea, and Japan. Korea and Japan, in addition to having some of the highest risk, also have a relatively low offset. Both economies have relatively high variable values -actually some of the highest- for non-energy intensive industry structure, oil stockpiling, and non carbon fuel switching; however, this cannot outweigh their considerable lack of domestic resource capacity. As a result, the only effective way to offset their oil supply risks is to continue with their policy goal of reducing their dependence on oil. The United States, unlike the other two economies, has a notably higher offset because it has a greater domestic resource capacity. However, as its domestic capacity decreases, it will similarly have to reduce its demand to effectively offset its risk.

HISTORICAL TREND OF OIL SUPPLY INDICATORS

Oil supply security, as mentioned previously, changes as a result of shifts in sectoral contributions to demand and economic development. As such, insight on historical oil security trends can prove beneficial for other economies that are following similar development trends. To further understand the essential factors that can shift an economy's final score and ranking, similar analysis for 1996 was conducted.

A comparison of the indicators for 1996 and 2004 reveals a number of interesting trends for this period [60.1].



60.1 Oil supply security indicators, 1996 and 2004
APERC 2007

The unfilled points are representative of 1996 values, while the larger shaded points are representative of 2004. The solid arrows reflect the trend in oil supply security indicators for each economy. The dotted pink line represents the ideal path that economies should follow over time, i.e. decreasing their supply risk and increasing their supply offset.

Both Japan and Korea have shifted their positions, lower and towards the right, following the ideal path towards increased supply security. This risk trend is largely a result of reduced oil consumption. During this period, Japan continued its fuel switching efforts within the electricity and industry sectors. As for Korea, slow GDP growth coupled with energy efficiency improvements in the industry and transport sectors have resulted in a moderate demand growth, as such reducing risks. In terms of offsets, both economies have switched towards a more non-energy intensive industry structure, as such reducing their oil intensity.

Thailand has also decreased its supply risk, even though it has also reduced its offset potential (due to a decline in its service-based industry sector and domestic resource capacity). This is largely the consequence of a decrease in oil imports as a result of the de-bottlenecking of refineries which created short-term refinery capacity increases.

There have also been shifts towards increased oil supply risk. This has occurred to Canada, China, Indonesia, and the United States.

In Canada and China, an increase in oil consumption has been the driving factor for this increase. Canada's increase in oil demand was dominated by road transport demand growth resulting from low population density and high living standards.

As for China, rapid industrialisation and rising vehicle ownership has contributed to this increase in consumption. Unfortunately, the growth of domestic crude oil production and expansion of refining capacity has not been able to keep up with this rapid increase in consumption (particularly of the transport sector). As such, this has contributed to an increase in net imports, from 10% to about 48% during this time frame. This has increased the economy's vulnerability to oil market variability.

Similar to the other two economies, Indonesia increased its oil consumption, as a result of a robust transport demand growth, during the time frame. However, although this was important, the main driver of change was the fact that the economy transitioned between being a net exporter to a net importer of oil. In 2002, Indonesia became a net importer due to declining production rates and lack of new exploration investment.[a] As such, this new transition created additional supply risks that the economy had previously not been subject to.

The final noteworthy observation is that the United States, during this time period, took over the number one position -from Korea-- on top of the supply risk ranking. This was the result of a number of factors. Similar to the others, the US increased its oil consumption (highest oil consumer of the ten economies). At the same time, its import demand grew at a faster rate than its income growth, as such increasing its risk level. Additionally, changes in gasoline specifications tightened refining capacity and increased oil product imports. Concurrently, domestic resource capacity decreased, reducing offsets that could have counteracted some of this additional risk.

	Oil Demand Elasticity	Oil Consumption (toe/capita)		Growth Rate of Oil Consumption (10-year period)	
		1996	2004	1996	2004
AUS	0.33	2.0	1.8	1.3	-0.3
CDA	0.30	2.7	3.1	-0.7	1.5
PRC	0.57	0.1	0.2	3.9	6.3
INA	0.90	0.2	0.3	4.0	2.3
JPN	0.46	2.2	2.0	2.5	-0.8
ROK	1.10	2.2	2.1	11.8	0.1
MEX	0.56	0.9	0.9	-0.7	-0.2
RUS	0.51	0.9	0.9	-9.6	-0.9
THA	1.15	0.6	0.7	10.9	2.0
USA	0.32	3.1	3.2	-0.4	0.7

61.1 Supplementary oil supply security indicators, 1996 and 2004

APERC 2007

Oil demand elasticity, for all economies except for Russia, was calculated for 1980 to 2004. Russia's oil demand elasticity was calculated for 1992-2004.

[a] Republic of Indonesia, Minister of Energy and Mineral Resources (2005). *Minister of Energy and Mineral Resources Regulation No. 31 year 2005 Concerning Energy Conservation Procedures.* Jakarta.

IMPLICATIONS

Based on the historical developments of the ten economies, there are a number of interesting trends that can provide insight. At early stages of development, economies experience rapid energy-intensive industrialisation, similar to China. This will initially increase their oil supply risk. However, as this phase of industrialisation stabilises, most economies begin to rely primarily on a non-energy intensive industry structure, which steadies or potentially begins to reduce oil intensity.

Regardless of an economy's stage of development, there are a number of strategies that can help reduce this oil supply risk. An economy can:

- **Diversify its energy sources**, primarily through fuel switching in certain oil intensive sectors. Historically, this has been most successful in power generation and industry sectors, as displayed in Japan and Korea;
- **Diversify energy import supply**, so that variability within a particular region -as a result of either political unrest or natural disaster- does not substantially impact access to oil supply; and
- **Improve energy efficiency** to restrain demand growth. This is particularly important in the industry and transport sectors.

It is important to note that for many economies, the transport sector, which relies 99% on oil, will be the primary driver of oil demand. Hence, in the medium to long term, improvements in transport efficiency combined with consistent development of alternative transport fuels are recommended to help restrain oil demand growth and reduce additional supply risks.

However, in the short to medium term, refining capacity will be a major driving force that impacts an economy's ability to meet future demand for oil. As a result of increased demand in the transport sector, it is increasingly important to augment the region's upgrading capacity to enhance the production of gasoline and diesel distillates. This is especially important since increased dependence on the Middle East for imports will require additional processing of heavy and sour crude oils.

At present, Asian refineries are insufficiently equipped, in terms of upgrading capacity, to meet both current and future demand within the region. This is a reality that must be altered, as the transport sector becomes increasingly important in the demand for oil.

As shown from historical practices, many economies find it more cost-effective to import a portion of petroleum products from the international market rather than construct additional refining capacity within the economy. This is particularly the case in economies where public opposition to construction of additional facilities is a prevailing hurdle. Although this practice is currently preferred, increased susceptibility to supply risks within future oil markets may outweigh its potential benefits.

In the end, there are a number of options that can help offset future oil supply security risk. However, a flexible pro-active policy approach is recommended since many of the most effective options have a significant lag-time before they have any significant impact on reducing an economy's risk to energy security.

ENERGY POLICIES & MEASURES TAKEN IN APEC TO ENHANCE ENERGY SECURITY

In response to rising oil prices and concerns over energy supply security, in 2004, APEC Energy Ministers identified risks posed by oil market volatility to the world economy and called for a continuation of the APEC Energy Security Initiative.

This section summarises APEC economies' past and present energy policies and measures developed to enhance energy security. Further analysis on certain *active* measures and their effectiveness within APEC member economies are presented at the end of the section.

NATIONAL ENERGY POLICY DEVELOPMENT

A brief overview of each economy's national energy policy development is presented below.

NORTHEAST ASIA

Hong Kong, China: Hong Kong has kept a free market policy and only intervenes, when necessary, to safeguard the interests of consumers, ensure public safety, and protect the environment. Energy efficiency and conservation are emphasised.

Japan: To reduce dependence on oil imports, the New National Energy Strategy (issued in 2006) has set a goal to reduce the share of oil in total primary energy demand from 50% to less than 40 % by 2030. In terms of resource diversification, Japan has encouraged private companies to become involved in upstream projects overseas and has negotiated with Russia to import crude oil from East Siberia and natural gas from Sakhalin project.

Korea: Korea's oil policy objectives have been to secure a stable supply and demand, reinforce the competitiveness of its oil industry, and build an open oil market. To decrease its dependence on fossil fuels, Korea has supported the expansion of nuclear energy. In addition, large-scale energy users have started developing voluntary agreements on energy savings. The establishment of trans-boundary energy supply systems in Northeast Asia have also been targeted to ensure energy supply security.

Chinese Taipei: In Chinese Taipei, policies to promote renewable energy and natural gas in the electricity sector have been established through the *Renewable Energy Development Law* and the *Natural Gas Business Law*. In terms of the oil industry, a petroleum fund has been set up to encourage oil and gas exploration and production.

SOUTHEAST ASIA

Brunei Darussalam: Brunei's energy policy focuses on expanding oil and gas industries and diversifying non-oil intensive industries.

Indonesia: Indonesia has developed a policy to diversify energy resources away from oil by (1) switching to natural gas in the industrial sector, and coal and natural gas in the electricity generation sector; (2) promoting biofuels in the transportation sector; and (3) promoting energy conservation. To foster oil fields investment, profit sharing between the government and contractors was raised from 15 to 20-25%. PETAMINA and MEDCO Energy have also been encouraged to get involved in overseas projects to search for new reserves.

Malaysia: The government intends to prolong the economy's energy resources by limiting the total production of crude oil. PETRONAS, a national oil company, is encouraged to venture energy-related assets overseas. Renewable energy, such as biodiesel, is in the process of development, with a production target of 500,000 tons per year by 2008. Malaysia has extended full support for the Trans-ASEAN Gas Pipeline and the ASEAN Power Grid.

The Philippines: The Philippines has initiated numerous legislative measures to secure energy supply. Public contracting rounds, initiated in 2003, have generated more investment in oil and gas exploration. In addition, a strategic target has been set to increase the oil and gas reserves by 20% within the next 10 years. Biofuels, such as coco methyl ether, ethanol, gasohol, alco gas and LPG have also been promoted to substitute for oil in the transport sector.

Singapore: Singapore has recently revised its "Singapore Green Plan 2012". The plan aims to improve energy efficiency by fuel switching from fuel oil to natural gas in the electricity generation sector; introducing green vehicles, such as hybrids and CNG vehicles; and developing a labelling programme for electricity appliances. Liquefied Natural Gas (LNG) has been identified as another alternative to meet its rising gas demand.

Thailand: In 2005, Thailand approved the *National Energy Strategy* to diversify energy resources, through the promotion of alternative energy and the development of new technology for energy conservation. CNG, gasohol and biodiesel have been promoted to replace gasoline and diesel. As part of the policy strategy to enhance long-term electricity supply, electricity purchases from neighbouring economies have been targeted.

Viet Nam: Viet Nam has developed the *National Energy Policy of Viet Nam*, which focuses on energy supply diversification and energy efficiency enhancements. The Greater Mekong Sub-region power grid interconnection project and Trans-ASEAN Gas Pipeline have been pursued for international cooperation. The government has also implemented various energy security measures, including oil and gas exploration enhancements to increase reserves and coal and new and renewable energy (NRE) development.

CHINA

By 2010, China aims to improve energy intensity by 20% of 2005 levels, through the modernisation and introduction of efficient technologies within the energy industry sector. A comprehensive set of policies have been implemented to (1) promote alternative fuels development and energy conservation to reduce energy import dependence; (2) strengthen the economy's ties with oil producing economies to secure stable supplies; (3) encourage Chinese oil companies to invest in overseas upstream projects to enhance energy supply security; and 4) build oil strategic reserves and open oil futures markets to allow companies to hedge price risks.

RUSSIA

Russia approved the *Energy Strategy of Russia to 2020* with the objective to reduce the economy's energy intensity, while sustaining its energy export position. Upgrading of oil production facilities and refurbishment of refineries are top priorities in the agenda. As an energy supplier, Russia's objective is to improve international energy security by increasing energy infrastructure development and energy exports to regional and international markets. With advanced nuclear technology and the technical experience, Russia is developing a "closed nuclear fuel cycle" technology, which uses recycled spent nuclear fuel to improve safety.

OCEANIA

Australia: To maximise the value of Australia's energy resources, the government creates exploration investment opportunities for bidders and limits its own petroleum exploration financing. The Australian Petroleum Production and Exploration Association (APPEA) started a strategy to promote growth in upstream petroleum and aims to outline a sustainable upstream petroleum industry to secure a long-term sustainable future.

New Zealand: Due to increasing oil demands and declining production rates, the New Zealand government has a policy to promote more domestic oil exploration. A package of incentives was released through the Minerals Programme for Petroleum to encourage domestic petroleum exploration.

Papua New Guinea: To attract oil and gas exploration activities, Papua New Guinea has a policy to offer income tax reductions and has removed the Additional Profit Tax. The National Energy Policy Statement and Guidelines will be released, in 2007, to enhance market transparency.

LATIN AMERICA

Chile: Chile has aggressively undertaken oil exploration and production activities overseas.

Peru: Peru has developed the Camisea project to promote natural gas and replace oil. New financial incentives to encourage investment in petroleum E&P and boost domestic oil and gas production have been introduced. The establishment of "Energy Ring" among Latin American economies has helped enhance regional energy security.

Mexico: Mexico has made efforts to increase investment in oil exploration and production. Modifications to the legal framework and the introduction of the Energy Sector Program are set to ensure investor entry. However, constitution amendments to allow private and foreign investors in the oil industry are still pending in congress.

NORTH AMERICA

Canada: Canada has increased off shore crude oil and oil sand production, promoted R&D for a hydrogen economy, provided financial incentives for energy efficiency house retrofits, and proposed tax credits for purchasing public transit passes.

United States: The US Congress passed the "Energy Policy Act of 2005" with the objective to increase domestic energy production, improve energy efficiency, and ultimately reduce energy import dependency over a ten-year period. Incentives for energy production and conservation are as follows: royalty relief for offshore deep-water oil and gas production, R&D loan guarantees for innovative technologies (advanced nuclear reactors, clean coal and renewable energies), subsides for farmers to increase ethanol production, tax credits for hybrid vehicle owners, and tax credits to home owners for the installation of energy efficient appliances.

POLICIES AND MEASURES TAKEN BY APEC ECONOMIES TO ENSURE ENERGY SECURITY

APEC member economies have begun to implement measures to curb their vulnerability to energy supply in the future. This development trend is influenced by the following factors: soaring crude oil prices, the existence of geopolitical risks, and the growth of oil import dependency in many economies.

To ensure energy security, it is recommended that economies enact policy to reduce both supply risk (increase the supply source and decrease the reliance on oil) and demand risk (increase the efficiency of consumption and decrease energy intensity).

Table [67.1] presents a summary of policies and measures taken by APEC economies. Economies, with the exception of China and Russia, are grouped regionally.

Financial institutions are noted in this table to identify how policy measures are financed. While some economies set up a specific fund for each policy, international finance organisations, such as the International Monetary Fund (IMF) and Asian Development Bank (ADB), also help finance projects. Foreign investment is encouraged in many economies as well.

The *economics* column of the chart identifies major policies taken by each economy to increase the cost-effectiveness of their energy sources. Appropriate policies vary from economy to economy, depending on their economic conditions and their status as either an energy export economy or an energy import economy. Within the APEC region as a whole, resource diversification, resource development and transport, and resource trading are the policies that are primarily implemented.

The last column, *technology,* identifies measures that aim to advance technology to help enhance energy security. Technology advancement is actively pursued in all regions, especially in terms of nuclear energy, clean coal technology, and renewable energy. Technology development and innovation will make a difference in addressing the 4A's of energy resource supply security in the future.

	Policy/Regulation	Financial Institutions	Economics	Technology
North East Asia	•Resource diversification •Regional cooperation •Reduce dependence on oil •Energy conservation	•Petroleum Fund (JPN,ROK,CT) •Public listing of INPEX (JPN)	•Focus on nuclear (JPN,ROK) •Oil pipeline from Angarsk (JPN) •Trans-boundary energy supply system (ROK)	•Light water nuclear reactor (JPN) •Clean coal technology (JPN)
South East Asia	•ASEAN+3 Energy Partnership •Resource diversification •Attract foreign investment in E&P •Renewable energy •Energy conservation	•ADB Bank •IMF •Foreign investment •Energy Conservation and Promotion Fund (THA)	•Global E&P (INA, MAS) •Hydro, coal, and renewable energy to replace oil •TAGP •ASEAN Power Grid •GMS (THA,VN)	•Cogeneration •Renewable energy technology •Biofuels (MAS, RP, THA) •NGV (THA) •CDM •Capacity building
China	•Renewable energy development •Overseas investment •Strategic oil stockpiling •Energy conservation	•Foreign currency reserve	•Diversification away from oil •Sino-Kazakhstan oil pipeline •Global E&P	•Renewable energy technology •Gasohol •CTL •CBM
Russia	•Energy Strategy of Russia to 2020 •Energy conservation •International cooperation	•Stabilisation Fund •Gazprom IPO •Foreign investment	•Upgrading oil production facilities •LNG exports •Sakhalin island oil and gas field development •East oil pipeline project	•Closed nuclear fuel cycle technology
Oceania	•Energy White Paper (AUS) •Intensify E&P •National Energy Policy Statement and Guidelines (PNG) •Energy conservation	•Foreign investment (PNG)	•Export of coal, LNG, uranium (AUS) •Import of LNG or CNG (NZ)	•Maximise energy resource production •Gasohol (NZ) •Clean coal technology (AUS)
Latin America	•Attract foreign investment in E&P •Energy conservation •Regional cooperation	•Foreign investment •IMF	•Energy Ring in South America •LNG imports (MEX,CHL) •LNG exports (PE)	•CDM
North America	•Energy Policy Act 2005 (US) •Asia Pacific Partnership (US) •Energy conservation	•Market capital •Project finance	•Expand LNG (US) •Oil sands development (CDA)	•FutureGen (US) •Hydrogen Initiative/ FreedomCar Partnership (US) •Generation IV nuclear technology (US) •ITER (US) •Methane to Markets Partnership (US)

67.1 **Policies & Measures taken by APEC Economies to ensure energy security**

In terms of reducing oil import dependence, it is evident, from the above-table, that importing economies try to minimise the negative impact of higher oil prices by reducing consumption (energy conservation) and searching for more alternative fuels. In contrast, oil exporting economies focus on maximising the use of their domestic resources.

Economies lacking in sufficient domestic resources focus on stabilising supply, while resource rich economies focus on domestic resource depletion and CO_2 emission constraints [67.2]. In addressing the energy security problem, energy import economies try to provide financial incentives to acquire confined resources, decouple economic activity with energy, and put more effort on energy diversification. Exporting economies focus on creating a competitive energy industry, encouraging investment for long-term profit, restructuring industry to operate efficiently, and upgrading energy production technologies.

	Import (Japan etc.)	Export (Australia etc.)
Objectives	Ease Impact	Profit Optimisation
Constraints	Domestic Resource	Depletion and CO_2
Measures		
Policy	Energy Security	Competitiveness
Financial	Captive Resource	Investment
Economic	Energy Decoupling	Industry Restructure
Technology	Diversification	Enhancement

67.2 **Comparison of actions taken by oil importers and exporters**

Actions taken by developing and developed economies in the APEC region in response to the energy security concerns are summarised in [68.1]. For developing economies, energy security policy is founded on the need for foreign infrastructure investment, regional cooperation for resources, capital and risk sharing, and renewable energy development.

Energy security policies for developed economies focus mainly on market mechanisms for resource allocations. Since these economies have ample financial resources, the objective is to investment in research and development of new energy to catch long term business opportunities in the energy sector.

	Developing (ex. ASEAN)	**Developed (ex. USA)**
Objectives	Social Stability	Market Efficiency
Constraints	Economic Strength	CO_2 Emissions
Measures		
Policy	National Security	Market Mechanism
Financial	Foreign Capital	Market Capital
Economic	Adaptive	Consistency
Technology	Renewable Energy	New Energy

68.1 **Comparison of actions taken by developing and developed economies**

ALTERNATIVE FUEL DEVELOPMENT: SUNSHINE PROJECT

INTRODUCTION

Japan's economy was significantly impacted by the 1970s oil crisis. A high dependence on oil imports, which were predominately from the Middle East,[a] increased the economy's vulnerability to oil market fluctuations. The negative effect of the crisis propelled Japan to make energy security its top priority. To help enhance its energy security, the government expanded its policy directives to include energy efficiency and the development of alternative fuels. The emergence of environmental concerns related to energy development additionally drove the government to put more effort on developing clean and efficient new energy technologies. Energy production through alternative methods, like a photovoltaic system, was considered the most effective option to provide clean and efficient energy.

[a] In the early 1970s, oil imports from the Middle East accounted for more than 70% of Japan's total primary energy demand.

Under this directive, the Ministry of Economy Trade and Industry (METI) initiated the Sunshine Program in 1974. This two-phased project (1974-2000) was introduced to increase the development of alternative energy -by investing in "new energy and technology"- to supply (by 2000) a considerable portion of the economy's total energy demand.

The first phase of the Sunshine Program was a national R&D programme. The programme, which was heavily funded by the government, formed the backbone for investment in new energy technologies. The second phase (started in 1984) developed a number of demonstration projects. Nevertheless, the photovoltaic (PV) market was still small, since demand for this product did not increase. Thus in 1994, the government started to play a larger role in the programme, providing subsidies for residential PV installation, technical guidelines for grid connected systems, and introducing net-metering in order to encourage the use of these systems.

PROJECT DESCRIPTION

The Sunshine Program was originally developed as a research proposal on solar energy technology in response to the oil crises in the 1970's. The programme was introduced in 1974 with a budget of about US$ 20 million.[b]

[b] Based on an exchange rate of 120 JPY/USD.

Funding is considered to be an integral component of the project; as a result, the *Special Account for Alternative Energy Development* was created under the enactment of the *Alternative Energy Act* in 1980. This special account, financed by an electricity tax and a tax on coal use, is exclusively dedicated to alternative energy development.

Initially, the government was interested the most in solar thermal power generation R&D; creating two 1-MW solar thermal power plant demonstration projects. Due to sunlight characteristics in Japan, the performance of these plants decreased significantly, as such making the technology unsuitable for power generation. Consequently, in 1981 the R&D focus was shifted to solar PV systems.

PV development, under the Sunshine Program, was supplemented by internal, PV system R&D efforts of major appliance producers. The establishment of government subsidies for R&D, coupled with the government's commitment to introduce a future market for solar PVs, were major drivers that encouraged private R&D efforts. The promise of a substantial future PV market stimulated several appliance producers to invest in PV technology, even though the government only offered small subsidies to individual firms.[c]

In the 1980s, a number of demonstration projects were promoted by New Energy Development Organisation (NEDO) to enable producers to accumulate experience in producing PVs and also to improve technologies through learning-by-doing. NEDO, in its effort to encourage improvements in PV system economics and efficiency, set annual cost reduction targets and applied pressure on PV producers by refusing to purchase solar cells that did not meet the required cost targets.

Following a decade of primarily PV technology development, the government diversified its strategy. In the early 1990s, the government introduced a policy to create a PV procurement market by (1) simplifying the procedures for residential PV installation, (2) providing technical guidelines for grid-connection, (3) introducing a net-metering system, and (4) creating a subsidy programme for residential solar PV systems. Furthermore, in 1994 a subsidy programme for 700-roofs was launched; JPY 2 billion (US$[d]) was allocated to provide investment aid and make the technology more cost competitive for consumers.

[c] Kimura, Osamu and Suzuki, Tatsujiro (2006). *30 years of solar energy development in Japan: co-evolution process of technology, policies, and the market*, Paper prepared for the 2006 Berlin Conference on the Human Dimensions of Global Environment Change: "Resource Policies: Effectiveness, Efficiency and Equity", 17-18 November 2006, Berlin.

[d] 2000 PPP

Year	Budget (JPY billion)	Number of Installations	Installed capacity (kW)	Subsidy Rate
1994	2.0	539	1,900	50%
1995	3.3	1,065	3,900	50%
1996	4.1	1,986	7,500	50%
1997	11.1	5,654	19,486	≤ 1/3
1998	14.1	6,352	24,123	≤ 1/3
1999	16.4	15,879	57,693	≤ 1/3
2000	14.5	20,877	74,381	JPY 270,000/kw; JPY 180,000/kW; JPY 150,000/kW
2001	23.5	25,151	90,997	JPY 120,000/kW
2002	23.2	38,262	141,438	JPY 100,000/kW
2003	10.5	46,760	173,687	JPY 90,000/kW
2004	5.3	54,475	200,155	JPY 45,000/kW
2005	2.6	36,754	136,304	JPY 20,000/kW
Total		253,754	913,575	

70.1 Subsidy budget for residential PV system, 1994-2005

Kimura, Suzuki, (2006) and New Energy Foundation

Private homeowners under this programme were obliged to apply under the following conditions:

- The PV system had to be installed at the applicant's residence.
- The PV system was grid-connected.
- The applicant had to enter a reserve flow agreement with the utility.
- The subsidy covered the costs of PV modules, peripheral (Balance-of-System: BOS) equipment, distribution lines, and installation.

At the beginning of the programme, the maximum subsidy amount was 50% of the total system cost, with an installed capacity limit of 5 kWp. Over time, the subsidy rate was decreased to give PV producers a strong incentive for cost reductions and to maintain the same level of customer burden.[e] As shown in [70.1], the subsidy rate was reduced from 50% of investment cost in 1994 to 3% of investment cost in 2005. At the end of 2005, the subsidy programme was terminated.

[e] The annual budget from the government was augmented from JYP 2.0 billion in 1994 to JYP 23 billion in 2002 and then decreased to JPY 2.6 billion in 2005.

ACHIEVEMENT

The Sunshine Program helped increase the number of household PV system installations in Japan. Within a year, the 700 roofs subsidy programme increased the number of installations from 539 (1994) to 1,065 (1995). By the end of 2005, 253,754 residential PV systems were installed, with a PV-generated capacity of 931,575 kW.[f] This achievement has made Japan the 3rd largest producer, after the US and Germany, of electricity generated from PV systems.

[f] The average installed capacity per household is between 3.5-3.9 kW.

LESSONS LEARNED

The establishment of a national solar PV system policy has helped the development of alternative energy and technology, which is an important step towards reducing energy import dependence.[g] Based on our analysis, there are a number of key features that contributed to the policy's success, namely:

[g] Although the program has proved successful in reducing the cost of PV technology, electricity generated from solar PV systems is still more expensive than that of other fuels.

Stable R&D support from the government. Since the beginning of the programme, the Japanese Government has assured consistent and sufficient financial support for PV system's R&D activities. This is very important for long-term development of new technology.

Market creation polices. It may take many years before PV technology becomes cost competitive within an economy. In order to have long-term private investment, the combination of R&D-push and demand-pull measures is crucial. Experience from the Sunshine Project indicates that a niche market (with consumers' support) provides an important footing for immature energy technologies. This is because a stable niche market can help promote expansion of the industry and technological development. This principle could be applied to the development of other new technologies.

Government commitment. To encourage private firms to invest in the development of alternative energy technology, a clear, transparent target and framework should be set by the government.

Ambitious targets set for the Sunshine Program encouraged private firms to participate in the market.

Availability of funding. A flexible and stable budget for demonstration and subsidy programmes, acquired by the Electricity Tax (Special Account), was vital for the survival of the subsidy programme.[h]

Consumer motivation. The increase in applications – despite the higher price of PV-generated electricity versus grid purchased electricity-reflected consumer awareness about the need to use environmentally friendly indigenous energy resources. A survey conducted within Japan in 1996 pointed out that the participants had a strong willingness to contribute to the protection of the global environment.[i]

[h] Thanks to this funding, the subsidy programme lasted from the 1980s to 2000s.

[i] Kimura, Osamu and Suzuki, Tatsujiro (2006). *30 years of solar energy development in Japan: co-evolution process of technology, policies, and the market*, Paper prepared for the 2006 Berlin Conference on the Human Dimensions of Global Environment Change: "Resource Policies: Effectiveness, Efficiency and Equity", 17-18 November 2006, Berlin.

IMPLICATIONS FOR OTHER ECONOMIES

Diversification of energy supply sources is recommended to enhance energy security; however, the extent of this diversification depends on an economy's interests and the availability of affordable resources and technology.

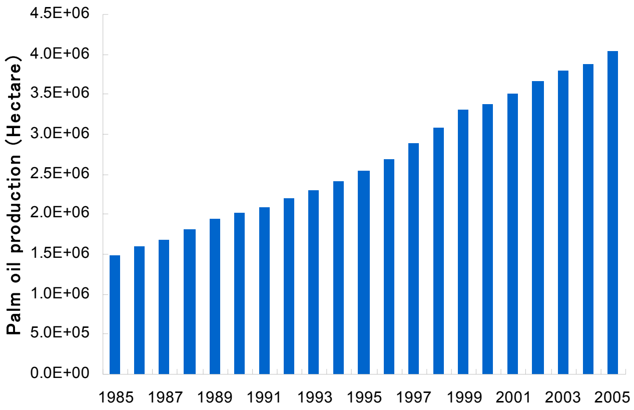
The development of new, alternative energy and technology is specifically important for economies with high energy import dependence. Although implementation can be costly, as shown by the Japanese Sunshine Program, alternative energy or in this case solar energy can still be competitive if its qualitative advantages (as a green, non-depletable, free energy) are taken into account.

In general, policy commitment by the government is recommended to ensure smooth operation of any renewable energy programme. Among others, it is the key to assure financial support to assist R&D for technology development and market creation for immature technologies to jump start to commercial production. In addition, government policy will also provide budget stability throughout the project life-time.

ALTERNATIVE FUEL DEVELOPMENT: BIODIESEL IN MALAYSIA

INTRODUCTION

Malaysia is currently the largest producer and exporter of crude palm oil in the world. In 2005, 4.05 million hectares (approximately 60% of agricultural land in Malaysia) were used for the cultivation of oil palm trees [73.1]. According to the Malaysian Palm Oil Board, Malaysia produced 14.96 million tonnes of crude palm oil in the same year; about 50% of the world's palm oil production.



73.1 Cumulative Oil Palm Production

Malaysian Palm Oil Board 2007

Currently, a search for environmentally friendly alternative fuel is emerging in the global scene because of the depletion of fossil fuels and concerns over global warming. Biofuel from oil palm is seen as one of the options to address these concerns. Since Malaysia is the largest producer of crude palm oil, it is natural that Malaysia has explored the potential of oil palm for producing biodiesel to be marketed internationally and domestically. There are a few factors that have driven the development of biodiesel in Malaysia, namely: (1) energy crisis in the mid-1970s, (2) fast depletion of domestic petroleum fossil fuel reserves, (3) growing environmental awareness, and (4) increasing energy demand.

The key objectives for palm oil biodiesel development are as follows:

- To help reduce an economy's dependence on petroleum diesel, particularly for the transport sector;
- To diversify palm oil usage to help reduce crude palm oil (CPO) stocks;
- To stabilise CPO price at a higher level; and
- To provide the world with an environmentally friendly alternative fuel.

PROJECT DESCRIPTION

BACKGROUND

The development of biodiesel in Malaysia started in the early 1980s. The government entrusted the Malaysian Palm Oil Board (MPOB) with the development of palm biodiesel technology. An abridged chronology of biodiesel development in Malaysia is listed below:

1982 An initial proposal for palm biodiesel development is conceptualised.

1983 A 'Palm Biodiesel' paper is submitted to the Malaysian Cabinet.

The Palm Diesel Steering Committee is formed.

1985 First palm biodiesel pilot plant is launched.

1994 The Cabinet approves the palm biodiesel project and the commercialisation of methyl esters production technology.

1998 Palm Diesel Steering Committee submits the final report on the palm biodiesel project to the Cabinet.

2001 Research project on low pour point palm biodiesel project is initiated.

2004 MPOB vehicles start to use Palm Oil/Petroleum Diesel Blends (B5).

2005 Commercial modular palm biodiesel plant is designed.

Commercial low pour point palm biodiesel plant is designed.

2006 The National Biofuel Policy is introduced.

Commercial palm biodiesel, with the brand name 'envo diesel', is launched (Envo diesel is a B5 fuel, which means it is a blend of 5% palm oil and 95% diesel.

Bank Pembangunan Malaysia establishes a biodiesel fund of RM500 million (Ninth Malaysian Plan).[a]

CURRENT STATUS

It is projected that the use of B5 nationwide will reduce diesel imports by 10% or 500,000 tonnes per year.[b] To achieve a biodiesel production capacity of 500,000 tonnes per year, about 9 biodiesel plants -with a capacity of 60,000 tonnes each- would need to be constructed. This will require an investment of RM360 million (US$100 million). It is estimated that the government could save up to RM0.4 billion (US$0.1 billion) through subsidies and taxes, while maintaining the commodity (Palm Oil) price above RM1000 per tonne.[c]

In March 2006, the government introduced the National Biofuel Policy to boost the palm oil industry, provide guidelines for biodiesel production and strategies to capture market opportunities. The policy is envisioned to: (1) help encourage the use of environmentally friendly, sustainable, and viable sources of energy to reduce dependence on depleting fossil fuels; and (2) enhance the prosperity and welfare of stakeholders in the agricultural and commodity-based industries through stable and remunerative prices.

[a] US$139 million (based on an exchange rateof 1 US$ = RM 3.6)

[b] Malaysia consumed 8.67 million tonnes of diesel in 2002, while the transportation sector accounted for 53% of the total diesel consumption. (National Energy Balance 2002).

[c] M. Hairol Abd Latip et al., *Role of Renewable Energy- Malaysia Country Report* at Asia Biomass Seminar, Japan, on January 2007.

CHALLENGES

The biodiesel industry is facing two major challenges, which are the environmental impact of palm oil cultivation and the controversial utilisation of crude palm oil as a fuel feedstock rather than a foodstuff.

ENVIRONMENT

Malaysia is aware of the negative environmental impacts of cutting down virgin rainforest for palm oil cultivation, which include the destruction of endangered species habitat and the prospect of eliminating certain plant species. Consequently, cutting down of virgin rainforest for palm oil cultivation is currently not allowed by the government. Rather than increasing palm oil production through increments of land area, the production of palm oil will be increased through (1) cultivation conversion from other crops to oil palm, (2) planting of high-yield species, (3) enhanced plantation management, and (4) more efficient technologies.

The National Biofuel Policy

The National Biofuel Policy has five strategic thrusts, namely: biofuel for transport, biofuel for industry, biofuel technologies, biofuel for export, and biofuel for a cleaner environment.

1. **Biofuel for Transport:** Diesel for land and sea transport will be a blend of 5% processed palm oil and 95% petroleum diesel, which will be called B5.
2. **Biofuel for Industry:** B5 diesel will also be supplied to the industrial sector for firing boilers in manufacturing**,** construction machinery and generators.
3. **Biofuel Technologies:** Research, development, and commercialisation of biofuel technologies will be adequately funded by both the government and the private sector (venture capitalists).
4. **Biofuel for Export:** The establishment of plants for producing biofuel for export will be encouraged and facilitated.
5. **Biofuel for a Cleaner Environment:** Increased use of biofuel will reduce environmental degradation, since the use of biofuel will reduce the use of fossil fuels; minimise the emission of greenhouse gases (carbon dioxide), carbon monoxide, sulphur dioxide and particulates.

Box quoted directly from Au Leck Chai, *Growth and Global Opportunities in Biofuels for Malaysian Palm Oil* (Tokyo: International Biofuel Conference, 2007), slides.

FOODSTUFF OR FUEL FEEDSTOCK

Palm oil, apart from being used as a feedstock for fuel production, is also used as feedstock for food production (cooking oil and margarine). The increased utilisation of crude palm oil as a feedstock for fuel will threaten the supply of feedstock for food. Therefore, in order to secure palm oil supplies for foodstuffs, the government has fixed a temporary quota on the amount of palm oil that can be utilised for fuel. Furthermore, the government has temporarily frozen the issuance of licenses for biodiesel plants. However, to ensure that there is a sufficient supply of palm oil for fuel purposes, Malaysia has set targets to put aside 6 million tonnes of CPO annually.

ACHIEVEMENTS

As a result of substantial government promotion and clear policy objectives, there are currently five biodiesel plants in operation with a total biodiesel capacity of 258,000 tonnes per year. The five biodiesel plants will require a total CPO and Pure Plant Oil (PPO) feedstock of 268,750 tonnes per year. In addition, as of December 2006, 84 biodiesel manufacturing licences were issued with a total installed capacity of 9.26 million tonnes of biodiesel.[d]

In terms of biodiesel technology development, the MPOB technology has successfully been used to produce summer and winter grade biodiesel that satisfies all of the stringent specifications of EN14214 and ASTM D6751 standards.[e]

To provide guidelines for the biodiesel industry, a Biofuel Industry Bill is scheduled to be tabled at the Parliament in 2007. The bill, once approved, will empower MPOB to regulate the biodiesel industry through both the issuance and revocation of biodiesel production and export licenses.

[d] Au Leck Chai, *Growth and Global Opportunities in Biofuels for Malaysian Palm Oil* (Tokyo: International Biofuel Conference, 2007).

[e] The minimum test requirements for Biodiesel blend extenders are specified in ASTM D6751 in USA and EN 14214 within Europe (http://www.biofueltesting.com/specifications.html)

LESSONS LEARNED

The steps taken by the government to develop biodiesel from palm oil are helping to enhance the economy's energy security. This will be achieved through reducing dependence on petroleum diesel, with the added benefit of stabilising CPO price in the world market - for which Malaysia is the world's largest producer and exporter of CPO.

The programme has achieved its goal of developing an environmentally friendly alternative fuel that can displace a significant amount of imported petroleum diesel, thus increasing energy security. The factors that contributed to its success are as follows:

- **Long-term government commitment and support in the early stage of development.** A long-term plan is important for R&D-focused activities. Even though utilisation of CPO as a fuel feedstock was not economical during the 1980s- due to low petroleum diesel prices- the R&D for palm biodiesel was still carried on because of this government support.
- **Clear direction of government policy**. Clearly set government targets are important because they give confidence to the industry/private sector to invest in biodiesel development. Furthermore, the development of biodiesel, as an environmentally friendly alternative fuel, was viewed holistically to determine the possible impact that its development would have on other sectors and on the environment.
- **The authorisation of a specific organisation** to implement R&D activities, supervise biodiesel technology development, and oversee biodiesel industry operation. Identification and empowerment of a specific organisation to oversee the development of biodiesel technology is very effective. The MPOB has successfully carried out R&D and developed both palm biodiesel fuel and biodiesel technology.

IMPLICATIONS FOR OTHER ECONOMIES

Alternative fuel development depends on an economy's objective for fossil fuel diversification and whether alternative fuel development can offer a cost effective and viable solution to the economy's energy security concerns. In addition, to sustainably develop alternative fuels, environmental protection objectives should also be clearly defined.

While the prospectus of developing alternative fuels to increase energy security is an attractive concept, its applicability is highly dependant on the availability of indigenous renewable resources that can sustainably support its development within an economy.

Economies with abundant renewable resources may initially want to focus on R&D and the development of a long-term plan for domestic use of these resources (as a method to displace fossil fuels). In the medium-long term, this plan can be expanded towards becoming a producer and exporter of environmentally friendly alternative fuels for the region.

For economies with little to no indigenous renewable resources, the adoption of an alternative fuel -such as biodiesel- may be a short-term strategy for energy resource diversification, with the added benefit of reducing environmental impacts from energy production.

CAPACITY BUILDING IN ENERGY EFFICIENCY & RENEWABLE ENERGY: DANIDA PROJECT IN MALAYSIA

INTRODUCTION

At present, Malaysia is rich in conventional energy resources and is a net energy exporter. However, it is projected to become a net energy importer by 2030, increasing its net energy import dependence to 32% (in 2030) from minus 57% in 2002.[a] In face of this looming transition, ensuring security of energy supply will be critical for the economy's energy policy planning.

[a] APERC (2006). *APEC Energy Demand and Supply Outlook 2006.*

Malaysia has considered several approaches to curb dependence on fossil fuels, such as the development of renewable resources and the pursuit of regional cooperations with neighbouring economies. This section specifically focuses on Malaysia's capacity building efforts in energy efficiency and renewable energy, which have been strengthened by cooperation with Danish International Development Assistance (DANIDA). In general they are called DANIDA projects.

[b] Denmark provides bilateral environmental assistance to countries in Southern Africa and Southeast Asia including Cambodia, Malaysia, Thailand and Vietnam: Ministry of Foreign Affairs of Denmark. http://www.um.dk/en.

Malaysia has received bilateral environmental assistance from the Danish "Environment and Disaster Relief Facility" (since 1994) to enhance the economy's endeavours for sustainable development.[b] Denmark is the second largest donor of official development aid to Malaysia.[c] Under the Environmental Cooperation Programme for 2003-2006, the Danish and Malaysian Government streamlined sustainability activities into five main focus areas: (1) Environmental Planning and Strategy, (2) Renewable Energy and Energy Efficiency, (3) Solid Waste, (4) Hazardous Substances, and (5) Biodiversity.[d]

[c] In 2003, major donor economies for Malaysia were Japan (US$79.2 million), Denmark (US$10.1 million), and Germany (US$6.3 million): Japan Ministry of Foreign Affairs. http://www.mofa.go.jp/index.html

[d] Embassy of Denmark, Kuala Lumpur. http://www.ambkualalumpur.um.dk/en.

PROJECT DESCRIPTION

The immediate objective of the Renewable Energy (RE) and Energy Efficiency (EE) focus area is to strengthen "capacity to significantly increase the role of renewable energy and energy efficiency in planning, policies and programmes."[e] There are three sub-components to this focus area, which include (1) integrated resource planning (phase two), (2) commissioning, outreach and replication, and (3) implementation of a national CDM action plan. The first two sub-components are a continuation of previous projects.

[e] Danish International Development Agency, Ministry of Foreign Affairs (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006. http://www.ambkualalumpur.um.dk/NR/rdonlyres/AB2C572D-6144-4FB1-A0BD-FBB32D3FCEED/0/EnergyComponent.pdf. pg. iv

A capacity building and training project on integrated resource and energy planning was originally designed in IRP-1 (2000 -2003). The major capacity building projects implemented in IRP-1 are listed below.

Pusat Tenaga Malaysia (Malaysian Energy Centre)

The project aimed to train employees of Pusat Tenaga Malaysia (PTM), that is, the Malaysian Energy Centre, as well as employees from other government agencies and institutions so that they could undertake sustainable and integrated energy sector development planning.[f]

A Centre for Education and Training in Renewable Energy and Energy Efficiency (CETREE)

CETREE was established at Universiti Sains Malaysia with the long-term objective of increasing energy awareness (in terms of energy's impact on society and the economy).[g] The centre provides publicity materials, training modules, a portable exhibition kit, and a website.[h]

Energy Commission

Under the Energy Commission Act of 2001, the Energy Commission was established to regulate energy supply activities and to enforce energy supply laws.[i] Capacity building of the Energy Commission was a critical aspect of the programme, since projects (specifically demand side management) needed to be implemented in cooperation with the Commission.

While IRP-1 focused on training, IRP-2 emphasised the establishment of a stronger foundation for national planning and decision-making on energy and analysis of available policy tools and their consequences.[j]

[f] The subjects covered by the project were as follows: (a) integrated energy planning and resource planning; (b) energy statistics and level of details; (c) energy database development; (d) technical power supply options and characteristics(conventional and alternatives); (e) power sector economics; (f) socio-economic analysis and methodology; (g) energy-environment relationships, external cost valuation; (h) energy models and development scenario; (i) regulatory instruments and incentives; (j) energy pricing (including green pricing); and (k) demand side management options and characteristics: (Danish International Development Agency 2003).

[g] Centre for Education and Training in Renewable Energy and Energy Efficiency. http://www.cetree.edu.my/

[h] DANIDA (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006.

[i] Seong Aun Chan (2004). Energy Efficiency – Designing Low Energy Building Using Energy 10.

[j] DANIDA (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006.

LESSONS LEARNED

The factors that contributed to the project's success are as follows:

Government commitment and clear policy objectives. Renewable energy and energy efficiency objectives were brought to fruition through proper national energy planning, specifically the establishment of clear targets and incentives to achieve these targets.[k]

It was not until the early 1990's that sustainable development and environmental concerns received serious attention, as political priorities in Malaysia. However, since this time, the Malaysian Government has continuously made strides to advance EE and RE. In the Sixth Malaysian Plan (1991-1995), the Malaysian Government recognised the importance of renewable energy and energy efficiency as contributors to sustainable development. In the Seventh Malaysian Plan (1996-2000), the development of a regulatory framework and implementation mechanisms to support renewable energy and energy efficiency were specified. Most recently, in the Eighth Malaysian Plan (2001-2005), sustainable development of energy resources is emphasised. Ultimately, the Malaysian Government's recognition of capacity building, as a valuable asset, was a significant factor towards the incorporation of renewable energy and energy efficiency into national planning.

DANIDA's continuous support. Certainly the Danish Government's continuous technical support, which matched the donees' needs, helped the Malaysian Government build up capacity in policymaking and planning. DANIDA has primarily provided technical assistance through a contract with a consultancy firm. For capacity building, the project started to develop capacity in energy planning and scenario development- mainly in PTM during IRP-1 and then on the needs of key energy agencies in national planning during

[k] Danish International Development Agency (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006.

[l] Danish International Development Agency (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006.

IRP-2.[l] According to DANIDA, however, the institutional and regulatory arrangements that promote energy efficiency have not been settled yet.[m] To enhance energy efficiency Malaysia will next need to use the capacity acquired through the bilateral cooperation to develop regulatory framework that is effective.

Target the government's policy making and planning divisions. Overall, a useful lesson learned from this Danish-Malaysian cooperation is that directly targeting the government's policymaking and planning divisions helped Malaysia achieve changes in the energy sector. This was probably effective because the planning system in Malaysia is relatively centralised. Nevertheless, this cooperation highlighted the importance of providing policy-makers and staff in charge of energy issues with necessary training, as an essential step toward development of renewable energy and energy efficiency.

[m] Danish International Development Agency (2003). Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006.

IMPLICATIONS FOR OTHER ECONOMIES

This case study exemplifies the importance of capacity building in implementing effective energy policy. Economies need to recognise that capacity building is a prerequisite to pave the way for policy that promotes renewable energy and energy efficiency. It enables the government to analyse and monitor the energy sector in a proper way and to collect and utilise necessary data for planning and designing programmes.

Subsequently, field-level capacity building should follow so that staff of implementing agencies can understand programme logistics and expectations and as such implement programmes efficiently and effectively. Ideal though it is, the development of both a vertical and horizontal information sharing network could be helpful to extend the effects of capacity building to all personnel. Mid- to long-term commitment might be required for effective outcomes; however, it is unquestionably important to train people in the energy sector and to establish a regulatory framework before advanced technology is introduced.

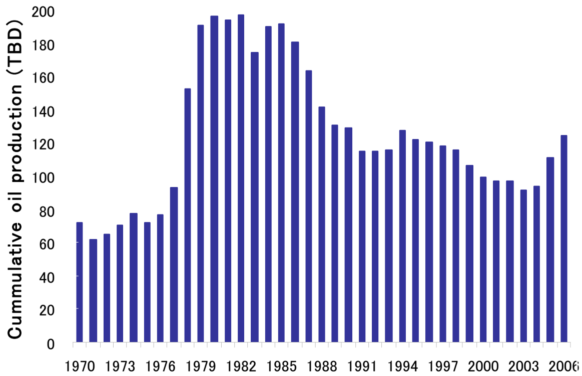
MARKET LIBERALISATION: PETROLEUM E&P IN PERU

INTRODUCTION

In the mid 1980's, Peru began experiencing declining oil production rates. Petroleum reserves- discovered during the 1970s to 1980s- were becoming depleted, while no new commercial reserves were discovered. In 1987, Peru became a net importer of crude oil. During 1992-1993, only eight wells were drilled- compared with a hundred in neighbouring economies such as Argentina and Colombia[a]- and in 2001 this number fell to just 3 new wells. Within a decade, Peru experienced a 14% drop in production [81.1], reducing its average yearly production of petroleum from 114.8 TBD (1991) to 98.2 TBD (2000). This negative trend reflects not only a fall in production, but also an increase in the economy's trade deficit.

[a] Schreck 1996, *Petroleum Investment Condition in Peru.*

In response to this slowdown in petroleum production, the Peruvian Government (in 1993) passed the Hydrocarbons Act. This act created a free market regime whereby private investments are promoted and guaranteed through a legal framework. Prior to the adoption of this legislation, the Ministry of Energy and Mines was responsible for the preparation, recommendation and implementation of policies regarding the energy sector. As part of the act's implementation process, PERUPETRO S.A. -a government company- was created to represent the Peruvian government in promoting and administrating petroleum contracts.



81.1 **Cumulative Oil Production in Peru, 1970-2006**

Perupetro S.A Estadistica petrolera 1994-2006 & Petroperu S.A. Memoria anual 1970-1993.

Petroleum contracts did not substantially increase at the outset, as such petroleum production and reserves continued to decrease. To increase contracts, the Peruvian government (in 2002) launched an aggressive campaign to promote investment in the petroleum sector. The campaign consisted of several measures, including a reduction in royalties payable to the government, less rigid terms and conditions for petroleum exploration and extraction, and a refund of the general sales tax on exploration, making investment in petroleum activities more attractive.

PROJECT DESCRIPTION

In 1993, the Hydrocarbons Act (known as LOH) established regulations for petroleum contracts. Essentially, the act provided a licensing scheme for the exploration, development, and production of petroleum in Peru. The following rules were created as part of this licensing scheme:

- PERUPETRO, a government entity, was formed to simplify the process of new investment.

- No limitations are placed on contractors to extend their contract areas.
- During the contract term, the contractors are bound to the same tax regime.
- No import tax for goods and raw materials during the exploration period.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
No. of Contracts	4	6	10	9	13	15	16	16	17	15	29	29	29	27	31	45	61
E invest. M. US $	19	41	30	20	29	37	104	187	228	113	17	31	31	12	42	25	132
P invest. M. US $	5	4	41	35	158	122	252	341	237	45	113	166	352	347	233	254	556
Production TBD	129	114.8	115.1	115.9	127.3	121.8	120	118.2	115.6	101.9	98.2	97.1	96.9	91.4	94.1	113.3	124.3

82.1 **Number of Contracts, E&P Investment, and Production, 1990-2006**

Perupetro S.A Estadistica.

Since 2002, a series of measures have been implemented to make the investment in hydrocarbons more attractive for investors. With the Supreme Decree 017 (promulgated in 2003) a new methodology has been introduced to determine the royalty payment. Contractors are able to choose between:

(1) A royalty rate scale between 5-20% on the Fiscalised Hydrocarbons valued,[b] based on production volume.
(2) A royalty fixed rate of 5% using an R factor [c] of 1.15 until the contractor recovers its costs. The royalty will then vary between 0-20%, based on the revenue and costs incurred during the previous year. The cap is set at 25%.

For existing contracts, signed prior to this law coming into effect, contractors were entitled to an equivalent discount, so long as the contracts were at the exploration stage and no commercial discoveries had been made.

[b] Value of Fiscalised Oil Production is the result of multiplying the Fiscalised Oil for a given valuation period by the Oil Basket Price for that period from which the corresponding transportation and storage cost has been deducted, if it is pertinent.

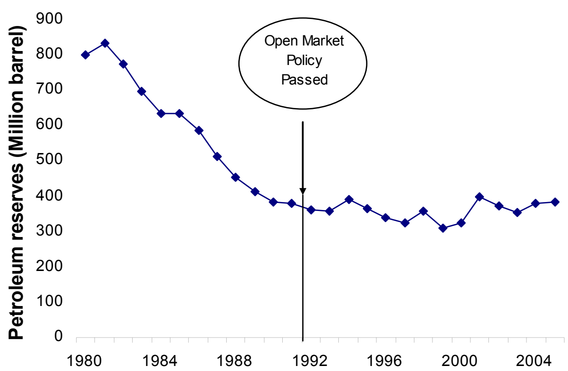
[c] R factor is a mechanism designed for the benefit sharing between the government and the contractor based on profitability calculated by using revenue and cost.

LESSONS LEARNED

Market liberalisation and an aggressive promotional campaign have increased private investment, creating a boom in the number of E& P contracts. Within four years of the campaign's commencement, the number of contacts awarded increased to 61 (2006) compared to 29 contracts in 2002. The production rate has also increased dramatically, from 91.4 TBD in 2003 to 124.3 TBD in 2006.

The campaign, though a clear policy objective to create a positive climate for investment, has achieved its goal of increasing production. The factors that contributed to its success are as follows:

Royalty fee reduction. Extracted petroleum is no longer State property. In other words, in exchange for a royalty payment to the State, the petroleum belongs to the contractor. Previously, 50% of all profits were taken by the state and the remainder went to the contractors. With the



82.2 **Evolution of Proved Petroleum Reserves in Peru, 1980-2005**

Perupetro S.A Estadistica 2005 and Petroperu S.A. 2005.

new regime, contractors now pay a royalty ranging between 5-25%, which is calculated through the newly created government company, PERUPETRO S.A.

Open market policy. Pricing is set by the market, without any intervention by the government. Based on the principles of free competition and free market entry, domestic oil requirements can be supplied by any player, foreign or local. The government has abolished the requirement to sell to PERUPETRO the petroleum required to supply domestic oil demand. This requirement is only enforceable by law in the event of an emergency disruption.

Reduction of entities involved in approval process. The number of government entities (bureaucratic obstacles) involved in the petroleum investment approval process has been reduced. Formerly, the approval process required permission from several ministers (such as the Council of Ministers), references from two ministers, and the approval of eight separate entities. According to the new regime, written approval is only required from PERUPETRO S.A.

Extension of exploration retention period. New contract terms include a retention period for exploratory well drilling and extend the time frame for oil exploration and extraction from six to seven years. Under the old regime, the exploration phase ended as soon as commercial extraction began. This posed a risk to oil companies, since it involved relinquishment of 50% of the contract area, as soon as the exploration phase was terminated. The exploration phase extension and the inclusion of a retention period, in some ways, have reduced the exploration risk, as well as the threshold risk problem.[d]

[d] Schreck 1996, *Petroleum Investment Condition in Peru.*

International arbitration. The ability to submit disputes to international arbitration has created a more positive perception of the economy. In the past, the absence of international arbitration was an impediment to attracting foreign oil companies, as these companies did not necessarily trust the economy's judicial system to be impartial.

IMPLICATIONS FOR OTHER ECONOMIES

Securing foreign E&P investment is facilitated through the development of a transparent legal framework, since investors rely primarily on a profit to risk analysis to determine their investment decisions. The investment environment created by the target economy is crucial, since any investor will consider (1) the tax system in place, (2) whether or not the economy has a strong rule of law, and (3) the economy's specific regulations for oil and gas resource access, before deciding to invest.

Market liberalisation, is also a concept worth taking into account, since it can enhance competition and investment within exploration and production sectors. Coupled with technology transfer from international oil companies, this measure can help improve the amount of reserves and increase production rates.

Overall, economies with domestic petroleum reserves that are facing declining rates of production could benefit from implementing a similar programme.

ENERGY PERFORMANCE STANDARDS: TOP RUNNER PROGRAMME

INTRODUCTION

In Japan, energy efficiency (EE) has played a critical role in energy policy because the economy has few natural resources and is heavily dependent on imports to meet demand. EE formally received the attention of policymakers after the oil shocks of 1973 and 1978 created energy supply vulnerability. In 1979, the government passed the Law Concerning the Rational Use of Energy, hereinafter referred as the Energy Conservation Law, to promote energy efficiency.

The industrial sector –as the largest energy consumer- was the top priority for EE improvements. Reductions in total industrial energy consumption were attained, on a voluntary basis, through the development of more efficient technology. Conversely, the total final energy demand of the ResCom (residential and commercial) and transport sectors have continuously increased. As of 2004, the shares of these two sectors accounted for more than half of total demand (increasing from 42.2% in 1980 to 52.2% in 2004). [a]

[a] For reference, the share of the industrial sector decreased from 55.2 percent in 1980 to 46.3 percent in 2004: The Institute of Energy Economics, Japan. http:www.ieej.or.jp

In response to the increase in sectoral energy demand, growing awareness of climate change, and Kyoto Protocol negotiations (1997), Japan commenced developing measures to reduce energy consumption and greenhouse gas emissions. Consequently, the Energy Conservation Law was amended in 1998, and the Top Runner Programme was introduced -in the same year- to advance energy efficiency (of machinery and equipment) in the ResCom and transport sectors.

PROJECT DESCRIPTION

Many economies use Minimum Energy Performance Standards (MEPS) to determine energy efficiency standards for machinery and equipment. Under MEPS, all targeted machinery and equipment must exceed a minimum value that is based on engineering studies, economic simulation models, and environmental impacts.[b]

[b] MEPS are the most accepted method worldwide.

The Top Runner Programme, Japan's version of an energy efficiency standards system, takes quite a different approach. These standards are derived from current energy efficiency trends in the market. Specifically, the standards are calculated by modifying the energy consumption of the most efficient product available in the market to reflect potential technological improvements.

The Energy Efficiency Standards Subcommittee, which is under the Advisory Committee for Natural Resources and Energy, is in charge of setting target standards for products. [c] To be classified as a *target-designated product,* the item must (1) be widely used in Japan, (2) consume a substantial amount of energy during operation, and (3) require EE improvements to reduce energy consumption. The final targets for these products are based on the reported findings of Evaluation Standard Subcommittees.[d] Each Evaluation Standard Subcommittee consists of academic experts, consumer representatives, industry representatives, and relevant machinery and equipment manufacturers. Since representatives consider potential

[c] The Energy Efficiency Standards Subcommittee establishes the Evaluation Standard Subcommittees for each type of machinery and equipment. Under the Evaluation Standards Subcommittee, working groups are established, if necessary. The Advisory Committee for Natural Resources and Energy, which is an advisory body to the Minister of Economy, Trade and Industry, authorises the set standards. Usually it takes one to two and a half years for a standard to be implemented from its initial deliberation: a year for the working group study, between a half year and a year for the subcommittee deliberations, and about a half year for other necessary procedures: Energy Conservation Centre, Japan. http://www.eccj.or.jp/index.html.

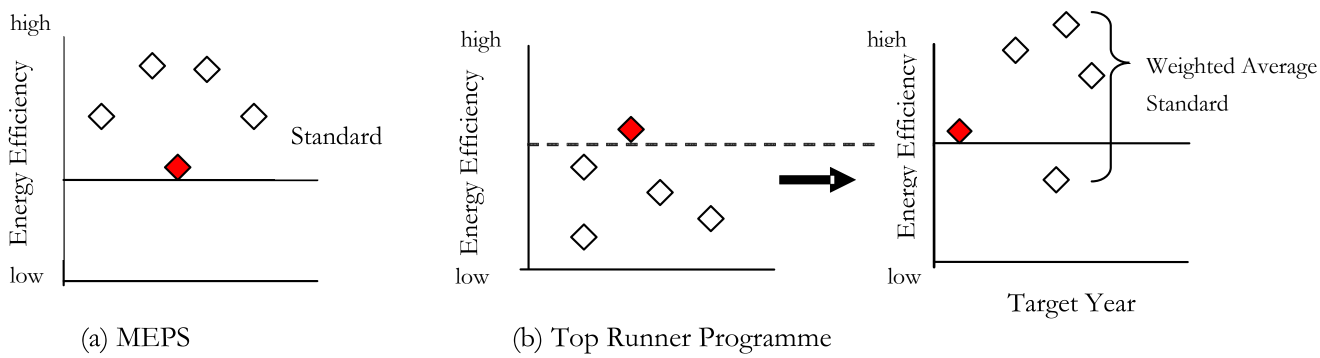
[d] An Evaluation Standard Subcommittee is established for each type of machinery and equipment to discuss draft standards in detail.

technological improvements, the standards are reflective of a realistic, attainable target that manufacturers can achieve by the set deadline.[e]

The main objective of these standards is to increase product efficiencies, while still enabling manufacturing flexibility. The programme accomplishes this through the development of different category-specific standards. To reflect differences in product specifications and their effect on energy consumption, multiple categories and standard values are created for each equipment type.[f] This scheme helps prevent market distortion, whereas the use of a single numerical value (as used in MEPS) could exclude products from the market. Under MEPS, products that do not exceed the standard are excluded from the market. Since the Top Runner Programme's standards are category-specific, it enables manufacturers to create an array of products for the market.

[e] A target year is set within four to eight years, depending on the time required to develop an appropriate technology.

[f] Standards for each product are separated in terms of product size, weight, and other physical dimensions. For instance, weight difference is used for cars' classification, monitor size for the TV sets, and server or client type for computers. For the TV sets, 20 categories are identified for cathode ray tube TVs, 38 categories for liquid crystal TVs, and 8 categories for plasma TVs: Energy Conservation Centre, Japan. http://www.eccj.or.jp/index.html.



86.1 **MEPS and Top Runner Programme**
APERC 2007

Another key component of the programme is that it requires a *weighted average* efficiency for assessment of target achievement [86.1]. The final product evaluation process, which occurs after the set deadline, requires each manufacturer and importer to meet a weighted average efficiency of all the units shipped within the *same category* in the target year. Thus, manufactures are able to produce machinery that is not necessarily energy efficient, but is highly demanded by consumers for other reasons. This provides manufacturers additional production flexibility, while this product differentiation provides consumers more choices.

ACHIEVEMENTS

As of January 2007, there are 21 *target-designated* products specified under the Energy Conservation Law.[g] Programme results show significant efficiency improvements; six target designated products have exceeded expected efficiency standards [87.1].

[g] The products include passenger vehicles, freight vehicles, air conditioners, electric refrigerators, electric freezers, electric rice cookers, microwave ovens, fluorescent lights, electric toilet seats, TV sets, video cassette recorders, DVD recorders, computers, magnetic disk units, copying machines, space heaters, gas cooking appliances, gas water heaters, oil water heaters, vending machines, and transformers.

Product Category	Expected Energy Efficiency Improvement	Achieved Energy Efficiency Improvement
TV Sets	16.4%	25.7% (FY1997 → FY2003)
VCRs	58.7%	73.6% (FY1997 → FY2003)
Air Conditioners[1]	66.1%	67.8% (FY1997 → 2004 refrigeration year[2])
Electric Refrigerators	30.5%	55.2%(FY1998 → FY2004)
Electric Freezers	22.9%	29.6% (FY1998 → FY2004)
Gasoline Passenger Vehicles[1]	23.0% (FY1995 → FY2010)	22.0% (FY1995 → FY2004)

87.1 **Top Runner Programme energy efficiency achievements**

Energy Conservation Centre, Japan.

[1] Cooling energy consumption efficiency is used for air conditioners efficiency and fuel efficiency (km/L) for passenger vehicles. As such, their energy consumption results are expressed in an inverse manner.
[2] The Japan Refrigeration and Air Conditioning Industry Association sets a refrigeration year which starts from October 1st and ends in September 30th of the following year for the industry. The 2004 refrigeration year is from October 1st, 2003 to September 30th, 2004.

LESSONS LEARNED

The factors that contributed to the programme's success are as follows:

***Name and shame* approach.** Since the Programme is based on the Energy Conservation Law, most manufacturers and importers are obliged to follow the regulations. In cases where products do not meet required standards, the Ministry of Economy, Trade and Industry (METI) will provide administrative advice to manufacturers. If the advice is not adhered to, METI will take a 'name and shame' approach, where the advice is made public, as such potentially damaging the manufacturer's reputation.

Information dissemination. To reinforce the Top Runner Programme, other programmes help disseminate energy efficiency information among consumers [88.1]. For example, the revised Energy Conservation Law (April 2006) encourages retailers to disseminate energy efficiency information to consumers.[h] Under the Energy Efficient Product Retailer Assistance Programme, shops selected as *Outlets that Excel at Promoting Energy-Efficient Products* are awarded by the government and obtain credits.

[h] The retailers are regarded as one of the important mediums of promoting energy efficient products.

As a caveat, information dissemination on the Top Runner Programme and energy efficiency is still considered a challenge, in spite of the implementation of these programmes. It still seems too soon to conclude that the average consumer is aware of the Top Runner Programme. However, the continuation of these information dissemination programmes can help reduce these trends.

Display Obligations	Manufacturers under the Top Runner Programme are required to display information on energy consumption efficiency, product name and type, and name of the manufacturer in a place specified by the Programme.
Energy- Saving Labelling Programme	The label includes four items: (1) a symbol showing the degree of achievement in energy efficiency, (2) energy efficiency standard achievement rate, (3) annual energy consumption, and (4) the target fiscal year.
Label Display Programme for Retailers	Retailers provide information about products displayed at their shops with the use of a uniformed energy-saving label, which presents a multistage (5 star mark) rating, an expected electricity bill value, and other information provided under the Labelling Programme. Currently, this programme is applied to air conditioners, electric refrigerators and TV sets.
Energy Efficient Product Retailer Assistance Programme	A home appliance retail shop that actively offers information and promotes energy efficient products is selected as an "Outlets that Excel at Promoting Energy-Efficient Products" and particularly excellent shops will be awarded by the government.

88.1 **Subsidiary programmes attached to Top Runner Programme**

Energy Conservation Centre, Japan.

Involvement of numerous stakeholders in efficiency standards deliberation process. Both the Evaluation Standard Subcommittee and the Energy Efficiency Standards Subcommittee include academic experts, representatives from various industries and trade unions, consumers, and related corporations.

The efficiency standards are drafted by the Evaluation Standard Subcommittee in a subjective manner and are then deliberated on by the Energy Efficiency Standards Subcommittee. Occasionally, the Evaluation Standard Subcommittee is not open to the public due to industry confidentiality matters. However, an interim report - prepared for the Energy Efficiency Standards Subcommittee- is provided on the internet to encourage public comment. After the public comments are taken into consideration, the interim report is finalised and sent to the Energy Efficiency Standards Subcommittee for approval.[i] By making the process transparent and involving all stakeholders, these methods help create a more effective standard system.[j]

[i] Energy efficiency standards that are approved by the Energy Efficiency Standards Subcommittee are reported to the WTO to avoid trade barriers to imported products: Energy Conservation Centre, Japan. http://www.eccj.or.jp/index.html

[j] In total, it generally takes from a year to two and a half year to enact legislation after targeted machinery and equipment is proposed: a year for the working group study, between a half year and a year for the subcommittee deliberations, and about a half year for other necessary procedures: Energy Conservation Centre, Japan. http://www.eccj.or.jp/index.html

Manufacturers' voluntary commitment and potential technology. Most importantly, the Top Runner Programme successfully drew out manufacturers' potentials on a voluntary basis without relying on a compulsory measure. In order to set target standards that are achievable by the target year, the aforementioned committees provided a forum for manufacturers' representatives to discuss relevant issues and potential technical improvements. In addition, the use of weighted average efficiencies in the evaluation process incentivise manufactures to produce high efficient products while providing popular but less-efficient goods. It is expected that once higher equipment efficiency is reached, the category's overall efficiency will be raised.

IMPLICATIONS FOR OTHER ECONOMIES

The Top Runner Programme, as a result of its success in achieving Japan's energy efficiency improvement objectives, can serve as model for policymakers in other economies

The Top Runner Programme is a unique energy efficiency standards system because of the way that its standards are developed. It may be difficult to transfer the exact same system to other economies as a result of differences in political context and available technology; however certain aspects can prove applicable.

For instance, the involvement of retailers in information dissemination is recommended to enhance public awareness about the energy efficiency of machinery and equipment used for daily life.

In terms of the standards development process, decision transparency and key stakeholder involvement throughout the process is highly recommended. In doing so, it is necessary for each economy to find its own metrics for reaching consensus on efficiency standards. However, it is recommended that final agreement be reflective of the economy's political and economic environment, market condition, and technology availability.

IMPLICATIONS

Energy security is enhanced by minimising the risks associated with supply availability, accessibility, acceptability, and affordability. As we have shown in this study, there are many risk factors ranging from the depletion of energy resources to technical & operational reliability of energy delivery systems. Moreover, new challenges to energy security, such as tightening environmental regulations and obligations to reduce emissions, have increased supply risk.

The development of energy security indicators has revealed that dependence on one key resource or supplier can increase energy supply risk. The level of risk, however, is different between economies and depends on the size and level of dependence. On a basic level, energy security can be enhanced through the use of sufficient indigenous resources. However, not all economies have sufficient indigenous supply to meet demand, as such increasing their vulnerability to energy price fluctuations and supply disruptions.

Potential countermeasures to reduce this resource supply risk will vary between economies. Thus, the implementation of any measure will have to depend on the specific situation within each economy. Based on the information acquired during this study, APEC member economies may enhance their energy security through the following measures:

Development of environmental friendly alternative fuels: To enhance energy security, energy supply diversification is recommended. Among APEC member economies, renewable energy has emerged as a means to enhance energy security and meet environmental obligations. In the power sector, wind, solar, and biomass are promising alternative fuel options to generate electricity. The transport sector's fuel mix can also be diversified through the use of biofuels. However, before doing this, it is recommended that policy makers address several challenges, such as the cost of development and deployment. For example, wind, solar and biomass have high generation costs compared to fossil fuels. Additionally, biofuels face challenges concerning food and fuel feedstock competition and environmental impacts during production that have to be balanced.

Another challenge related to renewable energy development is research and development (R&D) promotion. R&D is recommended since it helps reduce (massive) production costs and improves technology. According to the measures analysed in this study, R&D can perform effectively if governments offer a strong and consistent strategy to support it though either financial assistance or policy commitment. As the Sunshine project in Japan and Malaysia's biodiesel programme indicated, clear government commitment is critical until alternative fuels become commercially available. ***Markets alone will not solve these challenges; therefore, government policies to manage these barriers are recommended.***

Invest in new technologies which help diversify energy supply: Many attempts have been made to diversify energy supply and meet environmental targets. In terms of enhancing resource diversification, it is recommended that economies not only focus on the types of fuel sources, but also on technology advancement.

For example, Future Gen and Nuclear Generation IV (Gen IV) have demonstrated great potential for increasing the use of coal and nuclear respectively through technology advancement. ***Fossil-based technologies can be an option to allow the efficient use of coal and nuclear, which will help enhance primary energy portfolio diversification. .***

Facilitate cross-border energy trade and promote cross-border interconnection networks: Rapid electricity demand growth is observed in most of the economies in the APEC region. The total demand for electricity in APEC is projected to increase by about 3.2% per year, compared to an average capacity growth of only 2.4% a year. Thus, investment in energy transport and infrastructure development is needed to meet this demand growth. However, the cost for energy infrastructure development, in certain cases, is difficult to be borne by a single economy. As such, investment cost sharing and regional resource cooperations could be a solution. ***Interconnection networks (electricity and gas grids) are a preferred choice since energy security is not only limited to resource availability and geo-political concerns; it is also becoming more dependent on market mechanisms and regional cooperation.***

Facilitate international cooperation for technology, investment, and capacity building: Technology development plays a crucial role in dealing with long-term energy security. International cooperation could help enhance the effectiveness and efficiency of technology development. One essential key to success for international cooperation is to establish a third-party oversight body, which serves to facilitate the project among members. This kind of oversight body was observed in the Future Gen, Gen IV and ASEAN power grid programmes.

In addition, cooperation between developed and developing economies is also observed as a useful approach for funding and technology transfer. A well-known example is the Clean Development Mechanism (CDM), which encourages developed economies to provide financial and technological support to facilitate sustainable development in developing economies.[a] The DANIDA project in Malaysia is another example of a bilateral cooperation that intended to strengthen energy efficiency and renewable energy capacity building in policymaking and planning divisions. In this type of cooperation, it is important to reach a consensus that both sides can realistically agree to. ***International cooperation could be beneficial if it is based on member commitments to achieve common targets.***

[a] Developed economies due this in exchange for certified emissions reduction certificates (CERs).

Develop future framework for global commitment to environmental measures: Environment issues have become a global concern. The energy sector is considered a major contributor of emissions to the atmosphere, specifically greenhouse gases. Rising concern over local and global emissions will shape the growth of certain types of fuel use in the future. This will have a crucial bearing on economic growth and competitiveness among APEC member economies. A holistic approach is preferable for global climate change measures, since global climate change prevention should involve long-term measures as part of a wide-ranging sustainable energy security plan. For supply side management, the use of environmentally friendly resources, such as alternative fuels and advanced fossil-based technologies, is recommended. Furthermore, energy demand side management should not be neglected, especially in the commercial and residential sectors. Thus, ***long term resource planning that addresses environmental concerns and provides a framework for controlling energy-related greenhouse emissions is recommended.***

Repair public image of nuclear and coal: It is acknowledged that coal and nuclear will be used as key resources to depart from an oil-dependent society. However, both resources face a similar problem, that is, low public acceptance. In spite of its advantages in price and reserve volumes, coal became unpopular among the public, especially in developed economies, because coal use has been linked with environmental damages. Meanwhile nuclear has encountered public outcry over safety concerns, which are exemplified by the 'not in my backyard' phenomenon. ***In order for these two resources to increase in energy demand share, a policy designed to take a more fundamental approach to public awareness is recommended.***

Sufficient oil stockpiling capacity: Although oil stockpiling cannot offset long-term energy supply concerns, it can help address short-term oil supply disruptions. ***National strategic stocks or regional stockpiling (joint stocks) is recommended, particularly for economies with high import dependence, as a mechanism to stabilise the oil market and reduce vulnerability to emergency disruptions.***[b]

[b] For example, in 2005, Hurricane Katrina removed some oil supply capacity from the market, which resulted in price vulnerabilities.

Enhancement of energy conservation and efficiency: Energy security can also be enhanced through energy conservation and efficiency. Energy efficiency improvements and conservation can help curb energy consumption and supply imports in the long term. From the experiences' of the APEC member economies, ***energy efficiency and conservation projects seem to work effectively if they are developed with cooperation between the government and manufacturers, and a public awareness campaign.*** For example, the Top Runner programme in Japan was able to draw manufacturers' into voluntary action, which actually helped improve energy efficiency. In addition, programmes to enhance public awareness about energy efficiency also play a significant role to facilitate the effectiveness of energy efficiency programmes.

Public awareness/education campaigns: To further strengthen the efforts to address energy security, the development of public education campaigns to enlighten the public on the energy security issue, its implications, and how it will impact their life is also recommended. ***A clear, transparent plan, to address energy security, which can be grasped by the public, might help reduce objections during the policy implementation process.***

REFERENCES

INTRODUCTION

APERC (2006). *APEC Energy Demand and Supply Outlook 2006*. Tokyo, Japan

Brundtland Report (1987). *Sustainable development definition.* http://www.ace.mmu.ac.uk/eae/Sustainability/Older/Brundtland_Report.html.

Michael R. Fleishman, and David G. Howell (2005). *An Assessment of Oil and Gas Supply Stability for Leading APEC Economies.* Paper Presented at the APERC Mid-year Workshop, 10 November 2005. Tokyo, Japan

THE 4 A'S OF ENERGY SECURITY

Alberta Department of Energy (2004). *Alberta's Oil Sand.* Alberta, Canada.

Alberta Department of Energy (2006). *Talk about Oil Sands – Facts on Oil Sands.* Alberta, Canada.

APERC (2004). *Nuclear Power Generation in the APEC Region*. Tokyo, Japan

APERC (2005). *Renewable Electricity in the APEC Region: Externalities in Power Generation*. Tokyo, Japan

APERC (2006). *APEC Energy Demand and Supply Outlook 2006*. Tokyo, Japan

British Petroleum (2006). *BP Statistical Review of World Energy 2005*. http://www.bp.com

British Petroleum (2007). *BP Statistical Review of World Energy 2006*. http://www.bp.com

Canadian Association of Petroleum Products (2006)

Diana Sydney (2006). *National Oil Companies and International Oil Companies: Partnering for Success.* Paper Presented at the EMM8 Meeting (EBN 15), 15October 2006. Sakhalinsk, Russia.

David Lague. *In China, a trickle down effect on grain costs*. International Herald Tribune, 11-12 November 2006.

David L. Greene, Janet L. Hopson and Jia Li (2006). *Have we run out of oil yet? Oil peaking analysis from an optimist's perspective*. Energy Policy 34 (2006) 515-531.

Deloitte Research Institute (2005). *The Talent Crisis in Upstream Oil and Gas: Strategies to Attract and Engage Generation Y*.

Don Hinrichsen, Bryant Robey and Ushma D. Upadhyay (1998). "*Solutions for a Water-Short World.*" Population Report. Vol. XXVI, No. 1., September 1998.

Donald Gautier (2006). *Oil and Gas Resources: Uncertainty and Future additions to reserves.* Paper Presented at the APERC Annual Conference, 8 March 2006. Tokyo, Japan.

Energy Information Administration (2003). *The Global Liquefied Natural Gas Market: Status & Outlook*. Washington D.C.,USA. http:// www.eia.gov.

Energy Information Administration (2004). *International Energy Annual 2004*. Washington D.C.,USA. http:// www.eia.gov.

Energy Information Administration (2006). *International Energy Outlook 2006*. Washington D.C.,USA. http:// www.eia.gov.

Eric Sportt and Kevin Bambrough. *Investment Implications of an Abrupt Climate Change*. Sprott Asset Management. http:// www.sprott.com/pdf/climate.pdf.

Eureka County Yucca Mountain Information Office (2007). *Nuclear Waste Update, winter 2007*, Volume XII, Issue 1.

Gary Walker (2007). *Australia's LNG Industry*. Paper Presented at the APERC Annual Conference, 14-15 February 2007. Tokyo, Japan.

G.C. Watkins (2006). *Oil scarcity: What have the past three decades revealed?* Energy Policy 34 (2006) 508-514.

Guy Caruso (2005). *When Will World Oil Production Peak*. Energy Information Administration. Washington D.C.,USA.

H. Herzog and D. Golomb (2004). *Carbon Capture and Storage from Fossil Fuel Use*. Massachusetts Institute of Technology Laboratory for Energy and the Environment. Massachusetts, USA.

Hinrichsen et al. (1998). *Solution for water-short world population report*, Volume XXVI, No.1.

Institute of Energy Economics Japan (2007). *EDMC; Handbook of Energy & Economic Statistics in Japan*. Tokyo, Japan.

International Energy Agency (2003). *Renewables for Power Generation – Status & Prospects*. Paris, France. http:// www.iea.org.

International Energy Agency (2004). *World Energy Outlook 2004*. Paris, France. http://www.iea.org.

International Energy Agency (2005). *Oil & Gas Technologies for the Energy Markets of the Futu*re. Paris, France. http://www.iea.org.

International Energy Agency (2005). *Projected Costs of Generating Electricity – 2005 Update*. Paris, France. http://www.iea.org.

International Energy Agency (2005). *World Energy Outlook 2005*. Paris, France. http://www.iea.org

International Energy Agency (2006). *Natural Gas Market Review 2006 – Toward a Global Gas Market*. Paris, France. http://www.iea.org

International Energy Agency (2006). *Medium-Term Oil Market Report*. Paris, France. http://www.iea.org

International Energy Agency (2006). *World Energy Outlook 2006*. Paris, France. http://www.iea.org

International Energy Agency (2007). *Renewables in Global Energy Supply – An IEA Fact Sheet*. Paris, France.

International Monetary Fund (2005). *Oil Market Developments and Issues*. http://www.imf.org

International Monetary Fund (2006). *World Economic Outlook 2006*. http://www.imf.org

International Atomic Energy Agency (IAEA). http://www.iaea.org

IPCC (2007). *Carbon Dioxide Capture and Storage; Summary for Policymakers and technical Summary*. http:// www..mnp.nl/ipcc/pages_media/SRCCS-final/ccsspm.pdf.

Iran-Daily. http:// www.iran-daily.com.

James P. Bruce (2006). *Oil and Water – Will They Mix in a Changing Climate? The Athabasca River Story.* In Tin. T. (ed.), *Implications of a 2° Global Temperature Rise on Canada's Water Resources.* http:// www.sagecentre.org/sage/sagereport.pdf.

James Thomas (2003). *How the Oil and Gas industry will identify, recruit, and manage its human resources over the next decade.* Business Briefing: Exploration and production.

Japan Oil, Gas and Metals National Corporation. http://www.jogmec.go.jp/english/index.html.

John H. Wood, Gary R.. Long and David F. Morehouse (2004). *Long-Term World Oil Supply Scenarios: The Future Is Neither as Bleak or Rosy as Some Assert*, Energy Information Administration. Paris, France. http://www.eia.doe.gov

Ken Chew and Philip H. Stark (2006). *Perspective on Oil Resources Estimates.* Paper Presented at the AAPG Hedberg Research Conference, November 2006.

Lester R. Brown (2006). *Plan 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble. Thousands March Over Tortilla Crisis.* Reuters, 1 February 2007.

Maritime Union of Australia (2006). *Response to APPEA Issues Paper on Australia's Upstream Oil and Gas Industry.*

Mary Griffiths, Amy Taylor, and Dan Woynillowicz (2006). *Troubled Waters, Troubling Trends.* Pembina Institute. Canada. http://www.pembina.org/pdf/publications/TroubledW_Full.pdf.

National Energy Board (2006). *Canada's Oil Sands Opportunities and Challenges to 2015: An update.* Canadian Association of Petroleum. Canada.

National Petroleum Council (1999). *Natural Gas: Meeting the challenges of the nation's growing natural gas demand.*

Nature (2002). *Scorched the earth*, Volume 420, No. 6911.

Nuclear Energy Institute (2001). *The Outlook for Nuclear Energy in a Competitive Electricity Business.*: http://www.nei.org/documents/Status_Report_Competitive_Outlook.pdf.

Organisation for the Petroleum Exporting Countries (2006). *Annual Statistical Bulletin 2005.* http://www.opec.org

Peter R. Odell (2004). *Oil's Long Term Future; 85% yet to be explored.* Paper Presented to the Energy Institute Conference, "Oil Depletion: No Problem or Crisis?", 10 November 2004, London, United Kingdom.

Petroleum Intelligence Weekly (2006) Vol. XLV, No.50, 11 December 2006.

Pembina Institute Canada (2006). *Oil Sands Fever: The Environmental Impact of Canada Oil Rush.* Canada. http://energy.pembina.org/pub/203.

Power Scorecard, Electricity from: Nuclear Power.. http://www.powerscorecard.org/tech_detail.cfm?resource_id=7

Robert Meier, Janet Roundtree and Michael Schacfer (1998). *Oil Shock, Energy Supply Demand, Past, Present & Future.* Obele Oil Corporation "40 Year of Trusted Investment in Energy". http://www.obeleoil.com

Robert Skinner, Phd. (2006). *World Energy Trends: Recent Developments and their Implications for Arab Countries*, Oxford Institute for Energy Studies. May 2006.

Sueo Machi (2007). *Nuclear Energy for Sustainable Development.* Paper Presented at the APERC Annual Conference, 14-15 February 2007. Tokyo. Japan.

The Hubbert Peak of World Oil (2003). http:// www.oilcrisis.com/summary.htm.

The Institute for Agriculture and Trade Policy (2006). *Water Use by Ethanol Plants: Potential Challenges*. http:// www.iatp.org/

The Institute of Energy Economics Japan. http:// www.ieej.or.jp/

The Institute of Energy Economics, Japan (2006). IEEJ Energy Journal Vol.2 (2006).

The International Association of Maritime Universities. http://www.iamu-edu.org.

The New York Time. *Thousands in Mexico City Protest Rising Food Prices.* 1 February 2007. New York, USA.

Tim Johnson. *Australia opens door to nuclear power*. International Herald Tribune, 23 November 2006.

United Nations Development Programme (2006). *Beyond Scarcity: Power, Poverty and the Global Water Crisis*. Human Development Report 2006. New York, USA.

U.S. Environmental Protection Agency. *Clean Air Act*. http://www.epa.gov/air/oaq_caa.html/

U.S. Geological Survey World Petroleum Assessment 2000.

Wing-Gar Cheng. *Food beats fuel as China decides how to use farms*. International Herald Tribune, 23-24-25 December 2006.

World Coal Institute. *The Coal Resource: A Comprehensive Overview of Coal.* http://www.kolinstitutet.se/thecoalresource.pdf

World Nuclear Association. http://www.world-nuclear.org/info/inf02.html

World Nuclear Association (2007). *The Economics of Nuclear Power.* http//www.world-nuclear.org/reference/pdf/economics.pdf

ENERGY SECURITY INDICATORS

APERC (2006). *APEC Demand and Supply Outlook 2006*. Tokyo, Japan.

Blackwell Publishing (1992-2006). *World Oil Trade: An annual analysis and statistical review of international oil movements*. United Kingdom.

International Energy Agency (2006). *Energy database.* Paris, France.

Republic of Indonesia, Minister of Energy and Mineral Resources (2005). *Minister of energy and mineral Resources Regulation No. 31 year 2005 Concerning Energy Conservation Procedures.* Jakarta, Indonesia.

World Bank (1998). *World Development Indicators*. Washington, D.C., USA.

World Bank (2006). *World Development Indicators*. Washington, D.C., USA.

POLICIES & MEASURES TAAKEN IN APEC TO ENHANCE ENERGY SECURITY

APERC (2005). *APEC Energy Overview 2005*. Tokyo, Japan

APERC (2006). *APEC Energy Overview 2006*. Tokyo, Japan

APERC (2006). *APEC Energy Demand and Supply Outlook 2006*. Tokyo, Japan.

Asia-Pacific Economic Cooperation (2006). "*High Oil Price: Securing the Energy Supply in the Region". E-Newsletter, Vol. 7 No. 4*

Centre for Education and Training in Renewable Energy and Energy Efficiency (CETREE). Malaysia. http://www.cetree.edu.my.

Danish International Development Agency, Ministry of Foreign Affairs (2003). *Renewable Energy and Energy Efficiency – Malaysian – Danish Environmental Cooperation Programme 2003 – 2006*. Annex 3 to "Programme Document Malaysian Danish Country Programme for Cooperation in Environment and Sustainable Development". http://www.ambkualalumpur.um.dk/NR/ rdonlyres/AB2C572D-6144-4FB1-A0BD-FBB32D3FCEED/0/EnergyComponent.pdf.

Economic Planning Unit, Prime Minister's Department (2006). *Ninth Malaysia Plan 2006-2010.*

Embassy of Denmark, Kuala Lumpur. http://www.ambkualalumpur.um.dk/en.

Energy Commission (Suruhanjaya Tenaga) (2007) Information about the DANIDA Project, Malaysia. http://www.eest.net.my/

Energy Conservation Centre (2006). *Top Runner Program – Developing the World's Best Energy-Efficient Appliances (revised edition)*. Japan. http://www.eccj.or.jp/top_runner/index.html.

Energy Conservation Centre (2006). *Japan Energy Conservation Handbook 2005/2006*. Tokyo, Japan. http://www.eccj.or.jp/databook/2005-2006e/index.html.

Energy Information Bureau. Malaysia. http://www.eib.ptm.org.my/index.php.

F. Sato (2004). *The Recent Technology of Home Electrical Appliances Listed in the Top Runner Program.* Japan, Published in Energy/Resources Vol. 25. No. 5. 312-316.

International Energy Agency (2003). *World Energy Investment Outlook*. Paris, France.

Japan Ministry of Foreign Affairs. http://www.mofa.go.jp/index.html.

Jorge, Gastelumendi and ESTUDIO, GRAU (2003). *New Hydrocarbons Policy in Peru, Oil, Gas & Energy Law Intelligence*, Volume I, issue #02 – March 2003. http:// www.gasandoil.com/ogel/ samples/freearticles/article_45.html

Leck Chai Au (2007). Ministry of Plantations, Industry and Commodities Malaysia. *Growth and Global Opportunities in Biofuels for Malaysian Palm Oil.* A presentation by at the International Biofuel Conference, January 2007. Tokyo, Japan.

M Garcia Schreck (1996). *Petroleum Investment Condition in Peru.* Centre for Petroleum and Mineral Law and Policy. Scotland, United Kingdom.

M. Hairol Abd Latip et al., *'Role of Renewable Energy- Malaysia Country Report'.* Paper presented at the Asia Biomass Seminar, January 2007. Japan

Malaysian Palm Oil Board (2005). Report *Palm Biofuel and Palm Biodiesel Fuels for the Future.* Kuala Lumpur, Malaysia.

Malaysian Palm Oil Board (2007). *Malaysian Palm Oil Board Statistic 2007s.* Kuala Lumpur, Malaysia.

Ministry of Plantation Industries and Commodities Malaysia (2006). *The National Biofuel Policy.* Kuala Lumpur, Malaysia.

Ministry of Foreign Affairs of Denmark. http://www.um.dk/en.

Ministerio de Energía y Minas, Perú *(2006). Balance Nacional de Energía 2004*. Peru. http:// www.minem.gob.pe/archivos/dgh/publicaciones/oterg/BalanceNacionalEnergia2004.pdf

Ministerio de Energía y Minas, Perú (2006). *Estadistica Electrica 1999-2005*. Peru. http://www.minem.ob.pe/hidrocarburos/pub anuario_2005.asp

Ministerio de Energía y Minas, Perú (2006). *Plan Referencial de Hidrocarburos 2005 – 2014*. Peru. http://www.minem.gob.pe/hidrocarburos/pub_planreferen_2005-2014.asp

Ministry of Land, Infrastructure and Transport (2005). *White Paper on Land, Infrastructure and Transport in Japan*. Japan. http://www.mlit.go.jp/english/white-paper/mlit05/p2c7.pdf

New Energy Foundation. Japan. http://www.nef.or.jp.

Osamu Kimura and Tatsujiro Suzuki (2006). *30 years of solar energy development in Japan: co-evolution process of technology, policies, and the market*, Paper prepared for the 2006 Berlin Conference on the Human Dimensions of Global Environment Change: “Resource Policies: Effectiveness, Efficiency and Equity”, 17-18 November 2006, Berlin, Germany.

PERUPETRO S.A. (2003). *Policy for the Management of Exploration-Production Technical Information*. Peru. http://www.petroperu.com.pe/Main.asp

PERUPETRO S.A. (2007). *Policy of Exploration-Production Technical Information*. Peru. http://www.perupetro.com.pe/promocion-e.asp

Regional Energy Resources Information Centre (2005). *“High Oil Price and Energy Security in Asian Countries”. EE News, Vol.7 No. 4.*

Ristau Oliver (2001). *The Photovoltaic Market in Japan: Unquestioned Leadership of World Market*. http://www.solarserver.de/solarmagazin/artikelseptember2001-e.html.

Seong Aun Chan (2004). *Energy Efficiency – Designing Low Energy Building Using Energy 10*. CPD Seminar 7 August 2004. http://www.pam.org.my/Library/cpd_notes/Energy-Efficiency.pdf.

Swedish Environmental Protection Agency (2005). *The Top Runner Program in Japan – Its Effectiveness and Implications for the EU*. http://www.naturvardsverket.se/bokhandeln/pdf/620-5515-1.pdf.

The Energy Data and Modelling Center (EDMC), the Institute of Energy Economics, Japan (2006). *EDMC Handbook of Energy & Economic Statistics in Japan*. Tokyo/The Energy Conservation Center, Japan.

United Nations (2005).*Multidimensional issues in International Power grid interconnections*. New York, USA.

World Nuclear Association (2007).