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ALTERNATIVE DEVELOPMENT SCENARIOS FOR ELECTRICITY AND TRANSPORT

To 2020 For The APEC Region

2002

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FOREWORD

I am pleased to present the report of the study *Alternative Development Scenarios for Electricity and Transport to 2020 for the APEC Region*. This study builds on APERC's main publication, the *APEC Energy Demand and Supply Outlook*, the latest version of which was published in September 2002. One of the main results of the Outlook was the key importance of the electricity and transport sectors for the energy systems of APEC economies. Reference case projections show the serious impacts these two sectors could have on the environment, energy security and investment requirements if current trends are maintained.

This report explores alternative pathways for these two sectors, with sustainability as the primary driving force. Given the short time frame of the study, the year 2020, emphasis was given to designing challenging but feasible scenarios. The main findings are highlighted in the executive summary of this report.

This report is published by APERC as an independent study and does not necessarily reflect the views or policies of the APEC Energy Working Group or of individual member economies.

I hope this report will contribute to discussion of the sustainability of energy systems of APEC member economies.

Masaharu Fujitomi
President
Asia Pacific Energy Research Centre

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We also thank all members of the APEC Energy Working Group (EWG), APEC Expert Group on Energy Data and Analysis (EGEDA), APERC Advisory Board and other government officials for their stimulating comments and assistance with the study. Our thanks go also to the APERC administrative staff for their help in administration and publication of this report.

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LIST OF ABBREVIATIONS

APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
AUS	Australia
Btu	British thermal unit
CCGT	combined cycle gas turbine
CDA	Canada
CHL	Chile
CHP	combined heat and power
CO_2	carbon dioxide
COP	Conference of the Parties
CT	Chinese Taipei
DSM	demand side management
EGEDA	Expert Group on Energy Data and Analysis (APEC)
EIA	Energy Information Administration (USA)
EST	environmentally sustainable transport
EWG	Energy Working Group (APEC)
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GNP	gross national product
GW	gigawatt (10^9 watts)
GWh	gigawatt hour (one million kilowatt hours)
HKC	Hong Kong, China
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IGCC	integrated gasification combined cycle
INA	Indonesia
IPCC	Intergovernmental Panel on Climate Change
JPN	Japan
ktoe	kilo tonnes of oil equivalent
kW	kilowatt (= 1,000 watts)
kWh	kilowatt hour (= 1,000 watt hours)
LEAP	Long-range Energy Alternatives Planning System
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MAS	Malaysia
MEX	Mexico
MSW	municipal solid waste
Mtoe	million tonnes of oil equivalent
MW	megawatt (= 1,000 kilowatts)
MWh	megawatt hour (= 1,000 kilowatt hours)
NO_x	nitrogen oxides
NRE	new and renewable energy
NZ	New Zealand
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PE	Peru
PNG	Papua New Guinea
PRC	People's Republic of China

PV	photovoltaic
R&D	research and development
ResCom	residential and commercial sectors
ROK	Republic of Korea
RP	The Republic of the Philippines
RUS	The Russian Federation
SIN	Singapore
SO_x	sulphur oxides
tcm	trillion cubic metres
THA	Thailand
TPES	total primary energy supply
TWh	terawatt hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States (of America)
US DOE	United States Department of Energy
V2G	vehicle to grid
VN	Viet Nam

PREFACE

RATIONALE FOR THE STUDY

One of the main programmes of the Asia Pacific Energy Research Centre (APERC) is the production of the APEC Energy Demand and Supply Outlook. The first Outlook, which was produced in 1998, included a Protracted Crisis Scenario and an Environmentally Friendly Scenario. These were not scenarios in the true sense of the term, but rather alternative projections using modified economic growth assumptions. In addition, the environmental scenario was really only an energy conservation case, with lower than reference case growth in demand for coal for power generation. In September 2002 a new version of the Outlook was released. It provided a reference case, leaving the construction of alternative scenarios to this study.

The 2002 Outlook highlighted the key importance of the electricity and transport sectors for the energy systems of APEC economies, thus the focus of this study.[1] The alternative scenarios encompass both demand- and supply-side policies, initiatives and technologies that can assist the APEC region to move towards long-term energy sustainability, but at the same time supporting economic and social development. The environmental drivers are mitigation of greenhouse gas emissions as well as control of air and water pollution and urban congestion. The technology drivers are more fuel efficiency and cleaner power generation and transport technologies, some just emerging into the commercial marketplace, some already established and growing in importance, and some on the near horizon.

OBJECTIVE OF THE STUDY

The objective of this study is to produce alternative development scenarios for the electricity and transport sectors of APEC economies to 2020, driven largely by the concept of environmental sustainability, and having the APEC Energy Demand and Supply Outlook 2002 as a reference case.

Overarching assumptions driving the alternative scenarios are:

- Increased climate change awareness in the public domain and increasing policy responses from governments (the Kyoto Protocol is ratified by enough signatories to drive the whole climate response initiative forward in a meaningful fashion);
- Least life-cycle cost decisions are increasingly implemented – investment in long-term infrastructure that offers best economic prosperity in the longer term;
- Rapidly accelerated technology transfer from developed economies to developing as low-cost, conventional (old) technologies are increasingly seen to be an unsatisfactory solution even for poor economies. Although crude oil reserves are considered sufficient to allow for the projected increase in demand in the reference case, oil demand is curbed by the declining acceptability of oil.

In the electricity sector, the following assumptions shape the alternative scenario:

- The demand for better air quality in high-density urban areas drives changes in fuel choices and the types of consumer technologies adopted;

1 For details please see APERC (2002a).

- Accelerated improvement in efficiency of energy conversion in new power plants and the retiring of old power plants;
- Greater deployment of end-use energy efficiency technologies across all major sectors significantly delaying the need for additional generation capacity. Increased shift to less carbon intensive fuels (such as more natural gas replacing coal, and renewables gaining market share). Increasing contribution from new and renewable energy (NRE) sources such as wind power and solar thermal and solar photovoltaic (PV). A concerted effort is made to increase cogeneration through distributed power technologies for industrial and commercial buildings.

In the transport sector, the following assumptions shape the alternative scenario:

- Energy growth in this sector will continue to exceed that in other sectors, especially in developing APEC economies;
- The need to revert unsustainable trends in the transport sector drives the implementation of integrated and synergic packages of policies and measures, both within and in related sectors;
- Standards on emissions and fuel economy are harmonised internationally, in order to facilitate the penetration of low-emission and efficient vehicles;
- As transport alone accounts for over 15 percent of CO_2 emissions in the APEC region, the sector will increasingly be targeted by policy-makers seeking to reduce greenhouse gas emission levels. This translates into stricter fuel economy standards and greater promotion of alternate-fuelled vehicles;
- After introduction in the first decade of the 21st century of alternate highly energy efficient vehicle technologies (hybrid and fuel cell powered vehicles), consumer adoption in the second decade is rapid in developed economies. Essentially, hybrid and fuel cell powered cars are seen as the disruptive technologies that bring about the demise of conventional petrol and diesel powered motors in the long term (post 2020). However, it is not foreseen that fuel cell vehicles will have a major impact in the forecast period, given their cost, hydrogen supply infrastructure issues and expected penetration rates.

EXECUTIVE SUMMARY

OBJECTIVE

The objective of this study is to produce alternative development scenarios for the electricity and transport sectors of Asia-Pacific Economic Cooperation economies to 2020, having the APEC Energy Demand and Supply Outlook 2002 as a reference case.[2] The main driver of the alternative scenarios is environmental sustainability.

REFERENCE CASE

The APEC region has experienced rapid economic growth over the last two decades and is projected to continue doing so in the next two, especially in the fast industrialising economies in Northeast and Southeast Asia and in Latin America. The results of the Outlook 2002 highlight the importance of electricity in underpinning the region's economic growth, as well as the increasing relevance of the transport sector.

The Outlook 2002 forecasts that APEC's electricity consumption in 1999-2020 will increase at an annual average rate of 3.2 percent – the fastest growth of all energy forms – while transport energy consumption is expected to increase at 2.7 percent per annum – the fastest growth of all end-use sectors. Total investment in energy supply infrastructure to 2020 is projected to be in the range US$2.1-2.8 trillion, with electricity generation and transmission accounting for half of this total. On the other hand, the transport sector is forecast to account for 72 percent of incremental oil demand during the same period.

The results of the Outlook suggest that, in spite of progress in some areas, these two sectors will pose serious sustainability concerns, especially the transport sector.

CONSTRAINTS AND OPPORTUNITIES

Fossil fuels are expected to predominate as the energy source underpinning the modernisation of APEC economies over the next two decades, but the environmental, energy security, health and other impacts of large-scale use of these resources may constrain patterns of energy consumption.

On the other hand, a series of opportunities and emerging energy supply paradigms may contribute to shape a more sustainable energy future. The use of the Clean Development Mechanism (CDM), which is expected to gain momentum after the eventual ratification of the Kyoto Protocol, will likely foster technology transfer between developed and developing economies, and assist in fuel switching to reduce carbon emissions. Deregulation of the electricity and gas sectors is opening the way for major changes in the standard technologies employed to generate electricity, in the location of power generation units relative to centres of demand (meaning greater use of distributed power systems), and in the array of services available to consumers. Deregulation is also stimulating gas infrastructure development. In the transport sector, vehicle technologies are changing radically, as in the longer term are the fuels that vehicles will run on.

2 For details please see APERC (2002a).

Despite some dissenting views, oil supply is expected to meet demand, at least for the next two decades. However, a potentially more significant issue in the medium term will likely be oil's acceptability rather than its availability.

Coal is expected to continue to account for a significant percentage of power generation in economies such as Australia, China and the US, given its cost-competitiveness and abundance. However, environmental and climate change policies will impose the adoption of clean coal power generation technologies.

Natural gas is likely to play a pivotal role in the near and medium term, especially in Asia and Latin America. In these regions, demand for gas is driven by the power sector, with industrial and residential demand developing once basic supply infrastructure is established.

Global growth in nuclear power capacity has slowed significantly over the last decade due to increasing concerns over nuclear plant safety and large capital and decommissioning cost requirements in liberalising energy markets. On the other hand, increased energy security concerns and the need to reduce greenhouse gas (GHG) emissions may well extend the life of existing plants and spur investment in additions to capacity.

Non-hydro renewables are forecast to be the fastest-growing primary source in the world energy mix over the next two decades. However, due to the small base from which this expansion begins, the share of renewables will reach only three percent of primary energy supply by 2020 from the current two percent worldwide. The key factors underpinning greatly expanded exploitation of renewable resources will be government policies and measures to curb pollution and GHG emissions, policies to diversify the energy mix and enhance security of supply, and cost reductions.

ALTERNATIVE SCENARIOS

In the alternative scenarios a number of challenging but feasible policies and measures were applied to the electricity and transport sectors. Combined results show that in 2020 APEC could consume nearly 17 percent less energy and emit 24 percent less CO_2 than in the reference case, with better environmental performance and improved service. The table below summarises the contribution of each sector to reductions in fuel consumption and CO_2 emissions in 2020.

Table ES1 Scenario comparison on fuel consumption and CO_2 emissions in 2020

	Fuel consumption (Mtoe)	CO_2 emissions ($MtCO_2$)
Electricity		
Reference case	3,524	8,705
Alternative scenario	3,098	6,848
Transport		
Reference case	1,824	5,357
Alternative scenario	1,366	3,896
Reference - alternative	**884**	**3,318**

Note: Emissions include carbon dioxide, methane and nitrous oxide, and are expressed as CO_2 equivalent.

The above implies that considering changes only in the electricity and transport sectors, CO_2 emissions of all sectors could be 6 percent lower than in the reference case in 2010 (middle of the first commitment period of the Kyoto Protocol), and 15 percent lower in 2020. Given the projected growth in energy consumption, in 2010 and 2020 this would still be 1.65 and 1.87 times higher than the 1990 level, respectively.

ELECTRICITY

This scenario examined an alternative for future electricity supply to consider the effects emerging technologies and measures could have on electricity demand and supply in APEC over the forecast period in the context of mitigating electricity consumption and generating electricity in a more environmentally friendly manner. The reference case projections in the APEC Outlook 2002 were based on the most likely developments in the electricity sector as reported in each of the APEC economies' development plans, policies, resource endowment and other situations inherent to each of them. In the alternative case, we presented a 'what if' question and attempted to provide answers.

The possibility of moving away from the business-as-usual scenario was considered in the alternative supply case. The assumptions in this scenario include utilisation of proven natural gas reserves in each of the economies or importing natural gas through LNG and pipeline infrastructure; reduction in the building of coal-fired facilities; increased utilisation of new and renewable energy (NRE) such as solar, wind, small hydro, geothermal and biomass; use of nuclear power in energy import-dependent economies; as well as co-firing biomass in coal-fired power plants. It was also assumed that energy conversion efficiency or thermal efficiencies of fossil fuel-fired power plants will improve further than assumed in the reference case. Distributed generation was also considered in the grid electricity and cogeneration in the industrial and buildings sectors.

On the demand side, it was assumed that electricity demand could be reduced by utilising new, efficient end-use technologies in industries as well as the buildings sector, both commercial and residential. The annual growth rate estimated in the reference case of 3.2 percent was reduced to 2.6 percent using these assumptions.

Combining the assumptions in the supply and demand sides, a lower demand growth that will be met by more environmentally friendly supply was the resulting scenario. Results show that coal and oil consumption in electricity generation could be reduced by 17.7 percent and 4.9 percent, respectively. Natural gas and nuclear energy on the other hand could be increased by 6.7 percent and 8.0 percent, respectively. In addition, the contribution of NRE could be increased considerably. Biomass was estimated to increase by 69.5 percent, wind and solar energy by 37.5 percent, geothermal by 30.0 percent and hydroelectricity by 0.9 percent. Despite these increases, the share of NRE (including hydro) in the fuel mix will be only 14.5 percent, a slight improvement from 9.6 percent in 1999.

With the reduction of demand and increase in environmentally friendly energy sources in supply, CO_2 emissions in the APEC region in 2020 can be reduced by 21.3 percent. The highest reduction could be made in Group C economies at 26.4 percent, followed by Group B economies at 22.3 percent. Reduction in Group A economies could reach 16.8 percent.

TRANSPORT

The approach used to construct the alternative transport scenario is based on a simplified version of the environmentally sustainable transport (EST) initiative fostered by the Organisation for Economic Co-operation and Development (OECD). The scenario also incorporates views from the Sustainable Mobility project of the World Business Council for Sustainable Development (WBCSD).

For each APEC economy, an integrated package of policies and measures was designed. A wide range of regulatory, fiscal, investment and educational measures was considered in order to achieve environmental, health, economic and social goals and targets.

In general, the measures that are expected to have the greatest impact are fuel efficiency standards, the internalisation of external costs, transforming fixed costs into variable costs, investment in efficient and attractive public transport, and demand management (both in the road passenger and freight sub-sectors). In the long run, urban planning is expected to make an important contribution to reducing energy consumption while improving accessibility levels. CO_2 emissions trading after 2010, first in developed economies and later in developing ones, could provide a significant impetus to achieve less energy-intensive and more environmentally friendly transport systems. In some high-income economies such as Canada, Japan, Korea, Singapore and the US, the effect of fuel cell vehicles in reducing oil demand is projected to be noticeable towards the end of the forecast period.

Results of the alternative scenario show that transport energy consumption in the APEC region by 2020 could be 25 percent lower than in the reference case, equivalent to roughly 45 percent of APEC's transport energy consumption in 1999. Approximately 97 percent of projected savings will come from reductions in the road sub-sector, and nearly 3 percent from air transport. Cumulative oil consumption savings in 2004-20 are estimated to reach nearly 26 billion barrels, worth US$608 billion. Nearly 73 percent of total transport energy savings in APEC are projected to come from Group A economies, while Groups B and C will account for 9 and 18 percent, respectively.

For APEC, the average annual growth rate of CO_2 emissions in 1999-2020 is expected to reach 1.2 percent, compared with 2.8 percent in the reference case. Thus, emissions in 2020 could be lower by 27.3 percent or 1,461 $MtCO_2$ than in the reference case. This figure is 48 percent of total transport emissions in 1999. The share in emissions reductions by each economy group is projected to be almost equal to their share in energy savings.

In the alternative scenario, energy consumption and CO_2 emissions of Group A are projected to peak during the second half of this decade, and continue on a downward trend until the end of the forecast period.

CONCLUSIONS AND POLICY IMPLICATIONS

The achievement of these results will require policy changes together with sustained and concerted efforts among APEC economies. The active involvement of and cooperation between government, industry, citizens and research institutions is essential.

In the electricity sector, proactive policies on energy efficiency, on both the demand and supply sides, should be improved to be able to attain optimum environmental as well as economic benefits while meeting growing demand for electricity. A key area is the removal of market barriers to achieve wider adoption of demand-side energy efficiency technologies and measures. Similarly, on the supply side greater impetus should be given to options such as cogeneration, new and renewable energy, and less carbon-intensive fuels, including natural gas and nuclear.

In the transport sector, policy-makers can play an important role in achieving a more sustainable system, resulting in a win-win situation where accessibility levels and user satisfaction are improved, while costs and negative impacts are reduced. Given the global nature of the transport industry, international cooperation is considered critical in a number of areas, including harmonisation of fuel economy and emissions standards, transfer of vehicle technologies, sharing of best practice experience, and the long-term goal of building a transport system in which reliance can be placed on hydrogen-fuelled vehicles. A number of regulatory, fiscal, investment and educational policies and measures are available to achieve the goals and targets of a more sustainable transport system. A key consideration is that the packages of policies and measures should have synergy, be comprehensive, tailored to the conditions of the location, have an adequate time frame for implementation and involve relevant stakeholders from the early stages of the planning process.

CHAPTER 1

INTRODUCTION

The APEC region has experienced rapid economic growth over the last two decades, especially in the fast industrialising economies in Northeast and Southeast Asia and in Latin America. Total gross domestic product (GDP) for the developed APEC member economies almost doubled over this period, and the fastest-growing economies typically tripled the size of their GDP. This happened despite several disruptions in oil markets and the Asian financial crisis of 1997-98.

Rising economic strength in Asia has been accompanied by the utilisation of available and affordable fossil fuels to support rapid industrialisation, just as the ready availability and subsequent harnessing of fossil fuels − principally coal − to a rapidly growing industrial production capability underpinned the Industrial Revolution. Factories during the Industrial Revolution era were powered directly by steam engines, with electricity becoming a more common power source for industrial processing only much later historically.

The industrialisation process today does not follow the historical model so closely. Electricity is a much more vital driving force in the modernisation process, and growth in the services sector and in other 'information age' requirements such as telecommunications and information technology parallel growth in industrial processing capability.

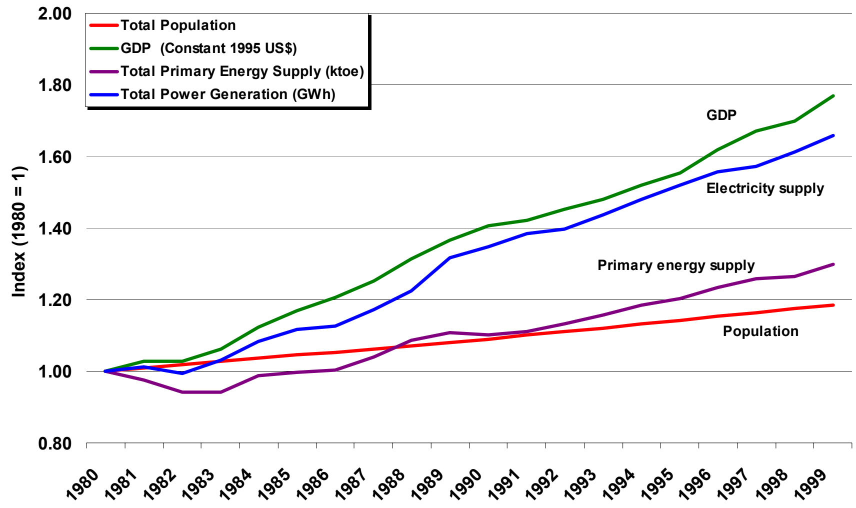
Fossil fuels still predominate as the energy resources underpinning the modernisation of APEC economies, but over the next two decades the environmental and health impacts of large-scale consumption of these resources may constrain patterns of energy consumption.

A number of important growth indicators can be used to demonstrate the importance of electricity in underpinning economic growth towards the end of the 20th century. Figure 1 shows indicators for population, GDP, total primary energy supply and electricity generation of developed APEC economies for the years 1980-99. There are two important factors underlying the fact that growth in electricity demand lags growth in GDP. First, although there is normally a very close correlation between electricity consumption and economic growth, for highly developed economies this relationship is weakening due to increases in the efficiency with which energy is used and the lower energy intensity of some high-performing sectors of modern economies. Secondly, many economies over-built electricity generation capacity until the early 1980s, but this is changing as deregulation and privatisation lead to a reduction in reserve capacity.

If one extends the time horizon back for 40 years, the importance of electricity in underpinning modernisation is more clearly demonstrated (Figure 2).

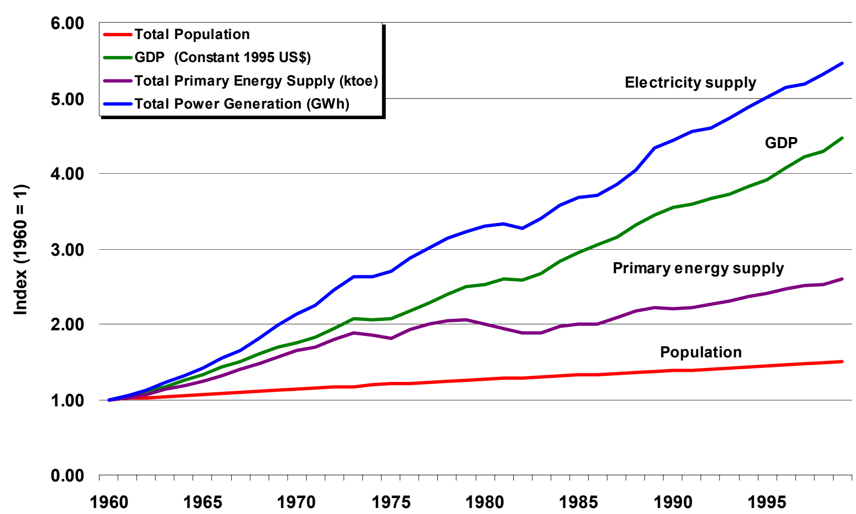
If one looks at the more rapidly developing economies in the APEC region over the last 20 years, the growth in electricity consumption relative to growth in other indicators is more dramatic than for developed economies over the same time period (Figure 3). This demonstrates the importance of electricity to the modernisation process for these economies. Although there is no energy data for these economies back to 1960, one can extrapolate the existing data backwards to show even more dramatically the fact that economic growth for developing economies can only come after massive investment in electricity supply infrastructure.

Figure 1 Population, GDP and energy supply indices for developed APEC economies (1980-99)



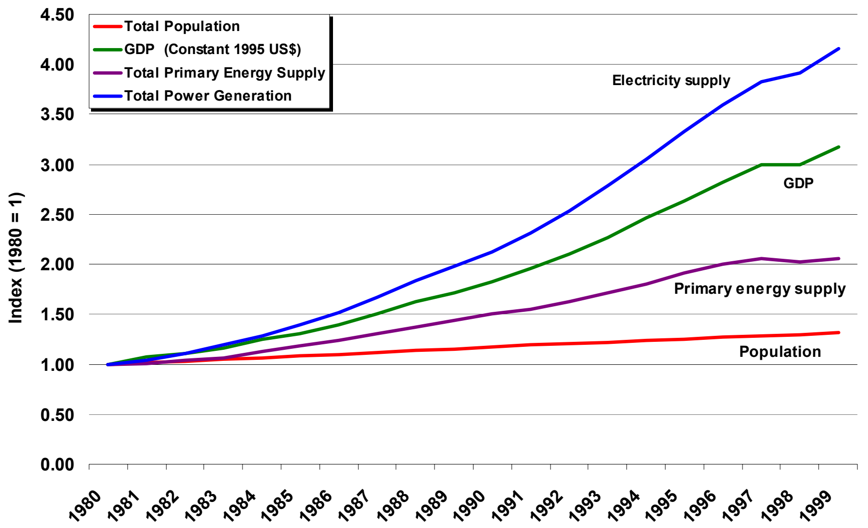
Source: IEA (2001a) and World Bank (2002).

Figure 2 Population, GDP and energy supply indices for developed APEC economies (1960-99)



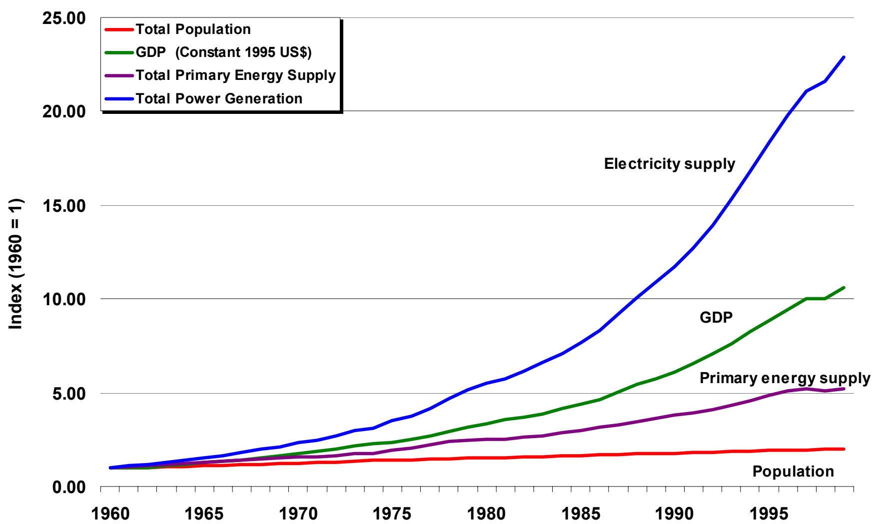
Source: IEA (2001a) and World Bank (2002).

Figure 3 Population, GDP and energy supply indices for developing APEC economies (1980-99)



Source: IEA (2001b) and World Bank (2002).

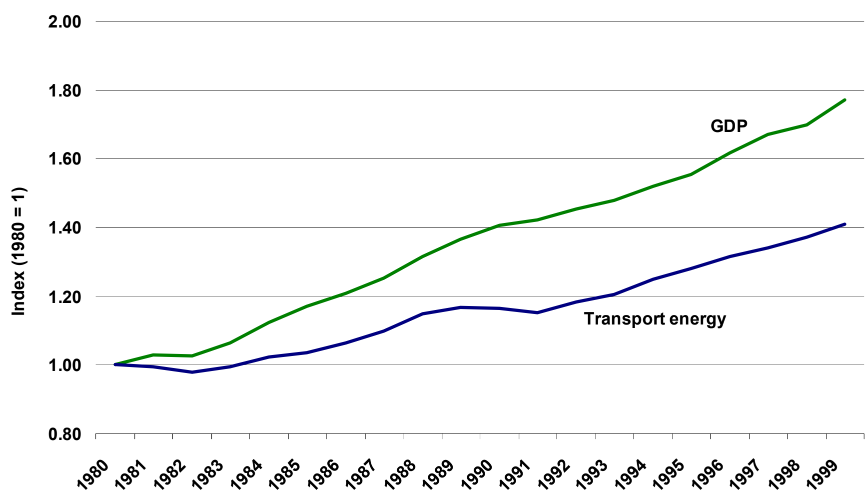
Figure 4 Population, GDP and energy supply indices for developing APEC economies (1960-99)



Source: IEA (2001b) and World Bank (2002).

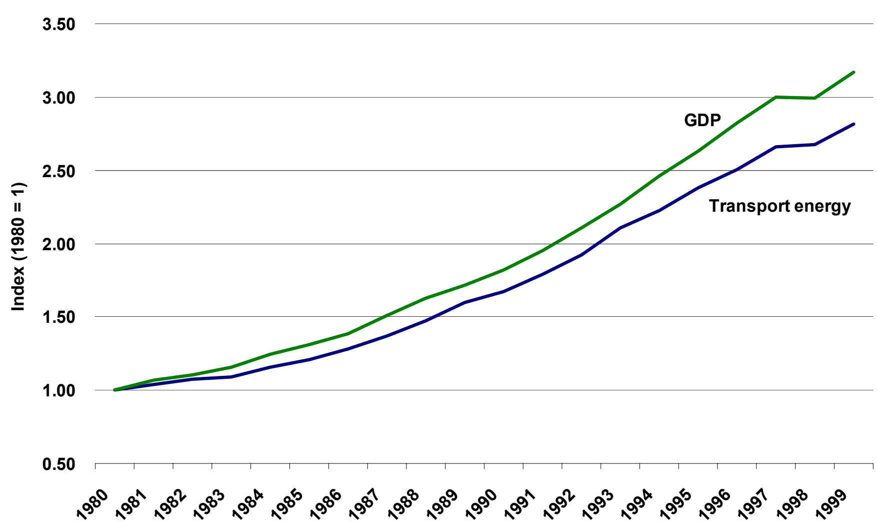
Transport energy demand growth over the last two decades has been lower than that of electricity supply (see Figure 5 and Figure 6). The figures show that as a consequence of the oil shocks of the 1970s, developed economies partially decoupled GDP and transport energy consumption, especially until the beginning of the 1990s. As Figure 6 shows, this was not the case in developing economies.

Figure 5 GDP and transport energy consumption indices for developed APEC economies (1980-99)



Source: IEA (2001a) and World Bank (2002).

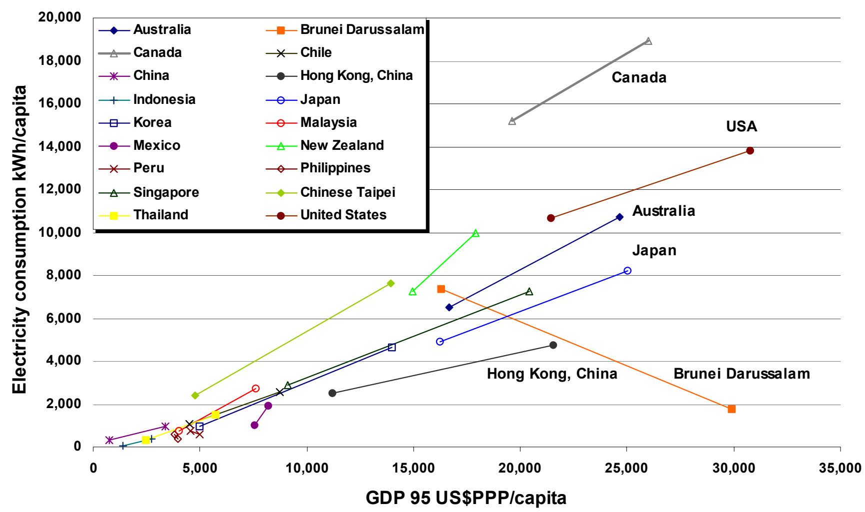
Figure 6 GDP and transport energy consumption indices for developing APEC economies (1980-99)



Source: IEA (2001b) and World Bank (2002).

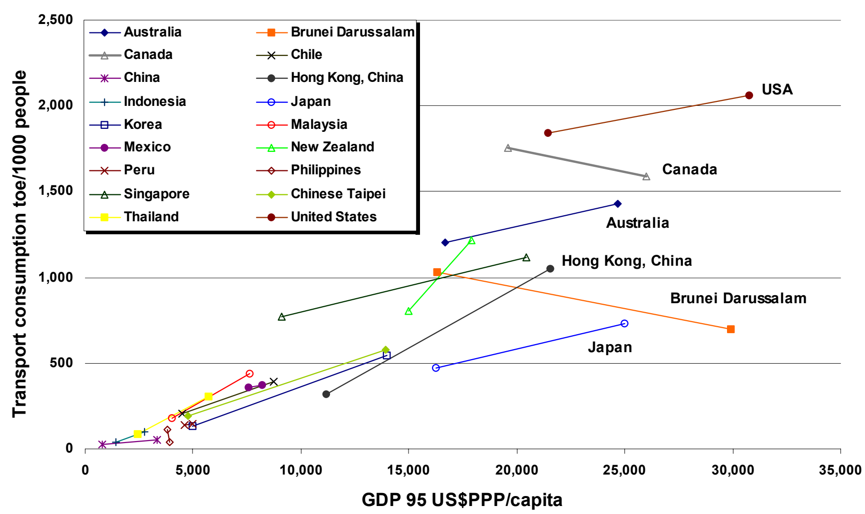
An alternative way of looking at the relationship between economic growth and the consumption of electricity and transport energy is presented below. The figures show that historically as incomes rise there is also a rise in electricity and transport energy consumption per capita. This relationship applies both within an economy and between economies. This well-known observation has been extensively studied and has been the basis for most econometric forecasts.

Figure 7 Electricity consumption per capita for APEC economies (1980-99)



Note: GDP data calculated using purchasing power parities, except for Brunei Darussalam and Chinese Taipei.
Source: IEA (2001a, 2002b) and World Bank (2002).

Figure 8 Transport energy consumption per capita for APEC economies (1980-99)



Note: GDP data calculated using purchasing power parities, except for Brunei Darussalam and Chinese Taipei.
Source: IEA (2001a, 2002b) and World Bank (2002).

However, a closer look at the figures shows that for a given per capita income there is a wide variation in electricity and transport energy consumption levels between economies. These variations can be explained in part by geography, climate and culture, but more importantly by many other factors, including economic structure, vehicle stock composition, and policies. Given the long life cycles and inertia of electricity and transport infrastructures, decisions taken at one point in time have long-lasting effects that can lead to significantly different levels of energy consumption. This is especially applicable to rapidly developing economies, which are doubling their power generation capacity and transport energy consumption in the lapse of one to two decades.

Looking at Figures 1 to 6 showing electricity generation and transport energy consumption, one can see that even small reductions compounded for 20 and 40 years can lead to significantly different levels. This is important for policy-makers to keep in mind when planning for the next 20 years.

In sum, development paths are neither unique nor immutable. This is what lies at the core of this alternative development scenarios study.

CHAPTER 2

THE REFERENCE OUTLOOK CASE

INTRODUCTION

This chapter presents a summary of the main results of the APEC Energy Demand and Supply Outlook 2002.[3] This Outlook, produced by APERC in September 2002, constitutes the reference case over which the alternative development scenarios are built.

The results are presented following the two groupings used in the Outlook, one by regions and the other by income level. The regional grouping classifies APEC economies into:

- North America: Canada and the United States
- Latin America: Chile, Mexico and Peru
- Northeast Asia: Hong Kong, China; Japan; Korea; and Chinese Taipei
- Southeast Asia: Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam
- Oceania: Australia, New Zealand and Papua New Guinea
- China
- Russia

The income groupings are based on criteria used by the World Bank. Group A includes economies classified by this institution as being high-income, with a GNP per capita in 1999 of US$9,266 or more. Group B includes economies classified as upper middle income, with GNP per capita of US$2,996-9,265. Group C includes the lower middle income and low-income economies with a GNP per capita of US$2,995 or less. The economies that fall into each group are the following:

- Group A: Australia; Brunei Darussalam; Canada; Hong Kong, China; Japan; New Zealand; Singapore; Chinese Taipei; and the United States
- Group B: Chile, Korea, Malaysia and Mexico
- Group C: China, Indonesia, Papua New Guinea, Peru, the Philippines, Thailand, Russia and Viet Nam

ELECTRICITY

REFERENCE CASE ASSUMPTIONS FOR ELECTRICITY

The main assumptions considered in the reference case for electricity are the following:

- Ongoing projects are included in the power plant line-up. Ongoing projects include those that are just awaiting financing and licensing requirements although actual construction works are not yet undertaken (up to those planned to be

[3] For details please see APERC (2002a).

commissioned by 2008). The nuclear power development programme of South Korea, for one, is considered a reference case, as there is strong government support for this programme. Another example is Malaysia. Although there is a significant amount of natural gas resources in Malaysia, government programmes support the building of more coal-fired generation to attain a diversified energy mix.

- System expansion in non-Annex I economies follows the least-cost principle, although a degree of diversification is observed depending on the available indigenous energy resources and energy infrastructures in the concerned economy.
- In the absence or insufficiency of indigenous natural gas, the proximity of an economy to supply sources is a major factor in the decision to build new natural gas-fired capacities.
- For the case of LNG imports, the cost of building LNG terminals is considered as a factor in the estimated price of natural gas input to electricity generating facilities.
- New natural gas pipelines (unplanned) do come not earlier than 2010.
- There will be an improvement in the thermal efficiency of generation facilities as shown in Table 1.
- High emission economies such as the US, Japan, China, Korea and Chinese Taipei will opt for additional nuclear power plants. However, regulations concerning nuclear power development in these economies are considered.
- The contribution from NRE is limited to the renewable portfolio standards (RPS) or the current NRE contributions (whichever is higher) of each economy with due consideration for the economy's power development plan.
- Grid connected distributed generation for peak load is built in economies where there are reliable natural gas distribution infrastructures.
- Exotic technologies like ocean thermal energy conversion (OTEC) for power generation are limited to demonstration projects and will not be commercialised in the outlook period.

Table 1 Technology options for power system expansion

Technology	Online year with order date of 2001	Size (MW)	Lead-time (Years)	Overnight capital cost in 2001 ($2000/kW)	Variable O&M (2000 Mills/kWh)	Fixed O&M ($2000/kW)	Heat rate in 2001 (Btu/kWh)	Heat rate in 2010 (Btu/kWh)
Conventional Pulverised Coal	2005	400	4	1,046	3.38	23.41	9,386	9,087
Integrated Coal Gasification - Combined Cycle	2005	428	4	1,250	0.80	32.67	7,869	6,968
Conventional Gas/Oil Combined Cycle	2004	250	3	435	0.52	15.61	7,618	7,000
Advanced Gas/Oil Combined Cycle	2004	400	3	546	0.52	14.46	6,870	6,350
Conventional Combustion Turbine	2002	160	2	323	0.10	6.45	11,380	10,600
Advanced Combustion Turbine	2003	120	2	451	0.10	9.16	9,020	8,000
Fuel Cells	2004	10	3	1,810	2.08	14.98	5,744	5,361
Advanced Nuclear	2005	600	4	1,772	0.42	57.23	10,400	10,400

Technology	Online year with order date of 2001	Size (MW)	Lead-time (Years)	Overnight capital cost in 2001 ($2000/kW)	Variable O&M (2000 Mills/kWh)	Fixed O&M ($2000/kW)	Heat rate in 2001 (Btu/kWh)	Heat rate in 2010 (Btu/kWh)
Biomass	2005	100	4	1,536	2.90	44.95	8,911	8,911
MSW - Landfill Gas	2004	30	3	1,336	0.01	96.31	13,648	13,648
Geothermal	2006	50	4	1,663	0.00	70.07	32,173	32,173
Wind	2004	50	3	918	0.00	25.54	10,280	10,280
Solar Thermal	2004	100	3	2,157	0.00	47.87	10,280	10,280
Solar Photovoltaic	2003	5	2	3,317	0.00	9.85	10,280	10,280

Source: US DOE - EIA (2002).

GENERAL CONSIDERATIONS

With the above-stated assumptions, the individual economies' policies on the electricity sector and the available energy resources in each of the APEC economies (Table 2), below are the considerations used in the decision for technology and fuel options in the future:

- Power generation technologies for future expansion of electrical systems in each APEC economy were selected based on an analysis of historical trends, resource availability and present or planned environmental policies.
- The generation technologies that will be used in most economies are gas-fired combined cycle and high-efficiency clean coal.

  The use of natural gas in combined cycle type plants is a rule for most economies, for its known characteristics of low capital costs, modularity, short construction times, and superior environmental performance. Advanced designs are already in commercial operation with fuel efficiencies of as much as 60 percent. However, fuel prices are not low and are likely to vary considerably in the future according to local conditions.

  Coal will be the choice in economies where there are sufficient available quantities of cheap resources. However, due to the need to reduce emissions, coal-fired plants will require the use of high-efficiency combustion and emission removal technologies that will not allow this type of plant to be as economical to operate as other available technologies. Coal plants will be important choices for additional capacity in Asian economies.
- More hydropower plants will be installed in economies where economic potential sites are still available, such as Australia, Canada, Chile, Indonesia, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Russia and Viet Nam.

  China has one of the most important hydro expansion plans in the region. The Three Gorges Dam, to be completed in 2009, will have 26 700-MW generators for a total of 18,200 MW. Another important hydro project is located in the upper part of the Yellow River, with plans for the eventual installation of 25 generating stations that will amount to a combined installed capacity of 15,800 MW.
- Nuclear energy will be an important part of the expansion plans in China, Japan, Korea and Russia. In Chinese Taipei a 2,700 MW reactor is already under construction, but plans for more nuclear plants in the future are uncertain.

  In Japan, where nuclear power accounts for 34.5 percent of electricity generation, this technology is counted on to meet its Kyoto emission reductions. Nine new reactors are planned to be online by 2008 with a total additional capacity of 11.3 gigawatts (GW).

In Russia, there are plans to either construct new nuclear power plants or extend the life of existing ones, due to its future policy to export most of its gas resources.

As much as 8 GW of additional nuclear capacity can be installed in China in the future.

Based on the above, the major fuel options in the APEC region will still be coal, natural gas, hydro and nuclear. Coal will be used mostly in Asia and Oceania while natural gas's share in North America and Latin America will continue to increase. Nuclear energy use in Asia will increase due to energy security and environmental concerns.

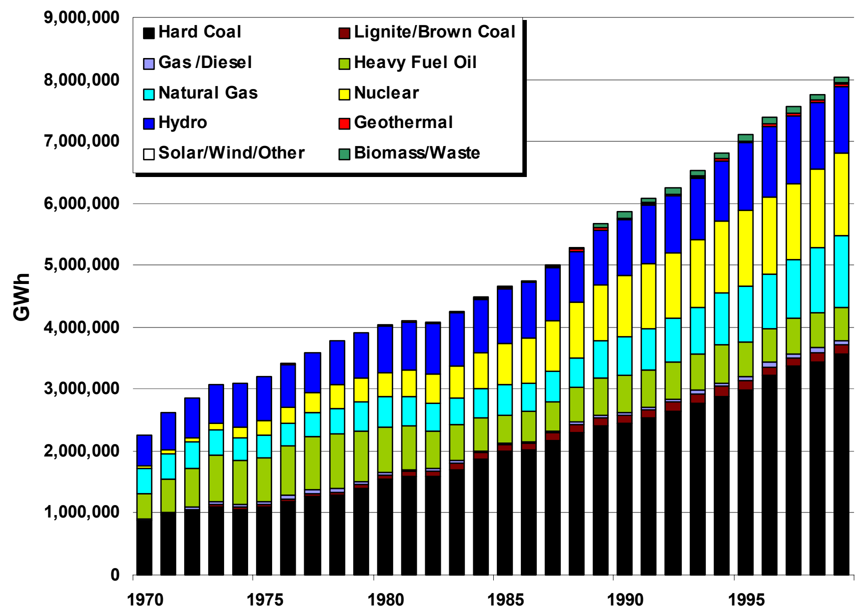
Table 2 Proven energy reserves in the APEC region

	Coal (Mt)	Oil and NGL (000' MBbls)	Natural gas (TCM)	Economic hydro potential (MW)
Australia	82,090	3.5	2.55	9,780
Brunei Darussalam	0	1.4	0.39	0
Canada	6,578	6.6	1.69	174,820
Chile	1,181	0.3	0.10	43,050
China	114,500	24.0	1.37	410,960
Hong Kong, China	0	0	0	0
Indonesia	5,370	5.0	2.62	13,050
Japan	773	0.0	0.03	37,180
Korea	78	0	0	4,890
Malaysia	4	3.0	2.12	28,310 [1]
Mexico	1,211	26.9	0.84	11,420
New Zealand	572	0.1	0.07	13,050
PNG	0	0.2	0.35	12,070
Peru	1,060	0.3	0.26	59,840
Philippines	332	0.2	0.08	5,870
Russia	157,010	48.6	47.57	277,230
Singapore	0	0	0	0
Chinese Taipei	1	0.0	0.08	3,260
Thailand	1,268	0.5	0.36	5,870
United States	249,994	30.4	5.02	122,640
Viet Nam	150	0.6	0.19	18,410

Note: 1: Technically exploitable capability.

Source: BP (2002) and WEC (2001).

Figure 9 Electricity generation by fuel type for APEC economies



Note: Russia and Papua New Guinea are not included in the graph or calculation due to a lack of data.
Source: IEA (2001a, 2001b).

In all the regional groupings included in the Outlook, the growth in the contributions of coal and natural gas to the power generation mix surpassed the total growth rate in supply and they were becoming more dominant in 1999 than in 1980 (see Figure 9). These growth rates are reciprocated by slower growth rates in petroleum and hydro contributions, which in some regions even had negative growth rates during the same period.

Table 3 shows annual average growth rates for power generation fuels for APEC economies for the period 1980 to 1999. For some economies, data is not available for the whole period, so results have been shown for the period of data availability. Natural gas has become a major fuel in Southeast Asia, growing by 6.4 percent per annum from 1980 to 1999. As a result its share in the power generation mix has increased from 0.8 percent to 43.6 percent over a span of 19 years. Natural gas has displaced petroleum as a power generation fuel, with the contribution of the latter declining at an annual rate of 1.3 percent. Electricity generation from nuclear energy also increased over the period, but is confined to only eight economies (Canada, China, Japan, Korea, Mexico, Russia, Chinese Taipei and the US).

Table 3 APEC annual average growth rates for electricity generation by type of energy input (1980-99) (in percent)

	Coal and coal products	Petroleum products	Natural gas	Nuclear	Hydro	Geo-thermal	Biomass /waste
Australia	4.4	-3.4	6.1		1.3		12.7
Brunei Darussalam		11.6	10.9				
Canada	3.2	0.5	5.7	3.5	1.7		9.3
Chile	11.0	3.8	21.2		3.2		12.9
China	9.8	-2.4	11.4	45.1[1]	6.8		41.8[2]
Hong Kong, China		-18.6	264.2[3]				
Indonesia	13.0[4]	4.4	47.4[4]		10.8		
Japan	7.7	-2.1	5.7	7.3	-0.1	7.3	3.6[5]
Korea	20.2	-2.4	44.6[4]	19.5	6.1		
Malaysia	29.5[6]	-2.3	37.3		9.3		
Mexico		4.6	6.5	39.0[7]	3.6	10.0	
New Zealand	7.9	-100.0	9.5		1.1	4.0	3.4
Peru		1.1	9.8		3.9		1.3
Philippines	24.2	-0.2			4.3	9.0	
Russia[8]	11.9	-20.5	-4.7	0.4	-0.4		
Singapore			21.3[9]				
Chinese Taipei	12.2	2.4	34.1[10]	8.5	6.1		
Thailand	13.8	1.7	77.3		5.0		
USA	2.6	-4.0	2.7	5.8	0.2	6.4	29.6
Viet Nam	3.9		53.9		12.4		
APEC	**4.8**	**-1.3**	**6.4**	**7.1**	**2.7**	**7.6**	**20.7**

Notes: Papua New Guinea is excluded due to lack of data.
1: 1993 – 1999. 2: 1994 – 1999. 3: 1995 – 1999. 4: 1986 – 1999. 5: 1982 – 1999. 6: 1988 – 1999. 7: 1989 – 1999. 8: Data for Russia 1990 – 1999. 9: 1992 – 1999. 10: 1990 – 1999.

Source: IEA (2001a, 2001b).

ELECTRICITY DEMAND FORECAST – REFERENCE CASE

The following table and graph summarise the reference electricity demand forecast for the period 1999-2020, by economy and sector. For further details please see APERC (2002a).

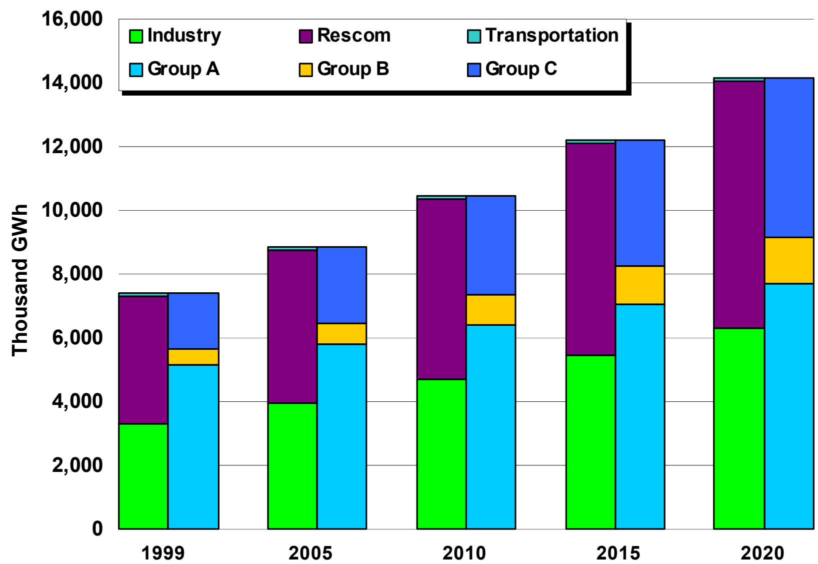
Table 4 Electricity demand forecast by economy and economy groups, in GWh – reference case

Economy	1999	2005	2010	2015	2020	AAGR*(%)
Group A						
Australia	168,542	194,863	219,345	245,466	272,765	2.3
Brunei Darussalam	2,349	2,850	3,312	3,842	4,439	3.1
Canada	461,256	517,845	564,975	609,401	655,862	1.7
Hong Kong, China	34,809	45,174	57,303	73,260	92,031	4.7
Japan	942,798	1,010,789	1,107,643	1,183,846	1,263,230	1.4
New Zealand	32,133	35,146	38,185	41,007	43,604	1.5
Singapore	26,249	34,968	44,494	55,950	69,324	4.7
Chinese Taipei	145,468	184,606	231,266	279,425	328,187	4.0
United States	3,337,798	3,751,489	4,146,651	4,562,878	4,979,889	1.9
Subtotal	*5,151,402*	*5,777,730*	*6,413,174*	*7,055,075*	*7,709,331*	*1.9*
Group B						
Chile	34,704	48,873	65,909	89,568	121,816	6.2
Korea	241,846	340,955	454,408	548,956	638,947	4.7
Malaysia	56,208	82,208	110,826	148,394	194,802	6.1
Mexico	151,679	210,939	297,908	393,953	487,520	5.7
Subtotal	*484,437*	*682,975*	*929,051*	*1,180,871*	*1,443,085*	*5.3*
Group C						
China	950,171	1,361,768	1,808,588	2,327,028	2,986,565	5.6
Indonesia	71,338	103,544	145,219	201,134	273,969	6.6
Papua New Guinea	2,000	2,278	2,638	3,057	3,530	2.7
Peru	16,515	18,732	23,536	29,792	37,940	4.0
Philippines	34,192	44,674	62,772	86,878	117,051	6.0
Russia	575,289	745,168	899,333	1,070,181	1,247,838	3.8
Thailand	81,457	94,243	130,943	186,880	252,100	5.5
Viet Nam	19,550	33,695	50,885	73,794	102,995	8.2
Subtotal	*1,750,512*	*2,404,102*	*3,123,914*	*3,978,744*	*5,021,988*	*5.1*
APEC	**7,386,350**	**7,386,350**	**10,466,137**	**12,214,690**	**14,174,404**	**3.2**

*AAGR - Average Annual Growth Rate

Source: APERC (2002a).

Figure 10 APEC sectoral electricity demand – reference case



Source: APERC (2002a).

ELECTRICITY SUPPLY PROJECTIONS

The power system expansion programmes of APEC economies suggest that coal will continue to play a major role in power generation, at least in the short term. Of 293 GW of ongoing and announced generation projects, 25.2 percent will be fuelled by coal. Although natural gas, hydro and nuclear may increase their share of the total fuel mix, the competitiveness of coal will make it the fuel of choice for quite a number of key economies in the immediate future. Table 5 shows the programmed capacity additions for the period 2000-05 for all of APEC.

Ongoing hydroelectric projects, mostly in China, total 60,102 MW, representing 20.5 percent of the new capacity additions. Other power plants, running on renewable energy such as biomass, geothermal and wind, form 1.8 percent or 5,303 MW of planned capacity additions.

Table 5 Programmed capacity additions in APEC economies (2000-05)

Plant/Fuel Type	MW	Share of Total
Coal	73,682	25.2%
Oil	41,302	14.1%
Natural Gas	81,557	27.8%
Nuclear	30,900	10.6%
Hydro	60,102	20.5%
Others	5,303	1.8%
TOTAL	**292,846**	**100.0%**

Source: Various energy programs of individual APEC economies.

For the longer term, electricity generation is projected to increase by 82.4 percent, or a rate of 2.9 percent per annum, between 1999 and 2020. This is a lower growth rate than the 3.2 percent per annum for final demand, as transmission and distribution losses are projected to fall from 17.1 percent of generation in 1999 to 12.8 percent in 2020.

Installed capacity is projected to increase by 1,252 GW, a 62 percent increase between 1999 and 2020. Together with the projected increase in generation, this implies that capacity utilisation will increase from 50.4 percent in 1999 to 56.7 percent in 2020.

Cumulative investment in power plants and transmission lines to 2020 is estimated to be in the range US$1.3-1.4 trillion, or roughly half of total energy infrastructure investment requirements.

All developing economies with the exceptions of Russia (3.8 percent) and Papua New Guinea (2.7 percent) are projected to increase their consumption at rates in excess of four percent per annum between 1999 and 2020.

China is expected to account for 30 percent of the increase in demand, with the US accounting for 24.2 percent. Russia is projected to account for 9.9 percent of the increase and may compete with Japan as the third-largest electricity consuming economy in APEC by 2020.

The combined cycle gas turbine is the favoured technology, with gas-fuelled capacity more than doubling from 402.5 GW in 1999 to 839.3 GW in 2020, a growth rate of 3.6 percent per annum. Generation from gas is expected to almost triple between 1999 and 2020, increasing from 1,514 terawatt hours (TWh) in 1999 to 4,399 TWh in 2020, a growth rate of 5.2 percent per annum. Its share of generation increases from 17 percent in 1999 to 27.1 percent in 2020. This is at the expense of all other main generation sources.

Incremental coal capacity is almost as great, increasing by 400.8 GW from 1999 to reach 1,113.6 GW in 2020. Projected coal generation increases by the largest amount, from 3,924 TWh in 1999 to 6,855 TWh in 2020, a growth rate of 2.7 percent per annum.

Capacity of renewable sources of energy such as solar and wind power is projected to increase rapidly. Hydroelectric power is projected to expand from 374.4 GW in 1999 to 611.7 GW in 2020, a growth rate of 2.4 percent per annum. New and renewable capacity is projected to increase almost eight-fold, from 5,249 megawatts (MW) in 1999 to 39,948 MW in 2020, a rate of increase of 10.1 percent per annum but still representing only 1.2 percent of total capacity in 2020.

Nuclear capacity is projected to increase from 203.3 GW in 1999 to 278.2 GW in 2020, an average growth rate of 1.5 percent per annum.

Electricity generation is projected to use 69 percent of coal supply and 45 percent of gas supply in 2020.

Natural gas should become the fuel of choice for electricity generation, given a combination of price, thermal efficiency and environmental considerations. It increases from 373.4 million tonnes of oil equivalent (Mtoe) in 1999 to 873.4 Mtoe in 2020, a growth rate of 4.1 percent per annum. Its fuel share is projected to increase from 17.8 percent in 1999 to 24.8 percent in 2020, at the expense of nuclear and oil.

Coal's fuel share should remain stable at just over 47 percent. In many economies it is the preferred fuel based on price and availability. It has the largest absolute increase in input energy, increasing from 989.1 Mtoe in 1999 to 1,658.8 Mtoe in 2020.

TRANSPORT

The transport sector comprises all activities related to the movement of passengers and freight. The four modes of transport considered in the reference case are road, air, rail and marine navigation. Pipeline transport is excluded.

APEC economies are in very diverse stages of development, but they face similar problems in this sector such as those concerning urban congestion, local air pollution, accidents, noise and land-use. In most economies transport is responsible for a major share of oil consumption, and energy security concerns have been a recurring issue. Developed APEC economies with GHG emissions targets acknowledge that transport is responsible for a significant share both of current emissions and of most of their growth, which is true for most OECD economies. Disposable incomes and production in developing APEC economies are experiencing rapid growth. This is impacting not only the transport sector with the above-mentioned problems but is also having a significant influence on the use of scarce resources. This is exacerbated by the desire to emulate the development patterns of more developed economies, especially in relation to car ownership and use.

ENERGY DEMAND TRENDS

Transport energy consumption in APEC (excluding Russia) doubled over the 28-year period from 1971 to 1999 – from nearly 480 Mtoe in 1971 to 985 Mtoe in 1999, an average annual increase of 2.6 percent. Statistics for Russia are available only from 1992; the inclusion of this economy raises the APEC total in 1999 to nearly 1 Gtoe (see Figure 11). Road transport accounts for the biggest share of this consumption with 81 percent, followed by air with 13 percent. The share of both modes is increasing, edging up from 93.7 percent at the beginning of the period to 94.8 percent by 1999. Rail transport and marine navigation make up the remainder, with shares of 3 percent and 2 percent in 1999, respectively.

In 1999, the US, Japan and China accounted for more than 70 percent of APEC's total transport energy consumption, with shares of 56, 9 and 7 percent respectively. These same economies accounted for more than 60 percent of the increase in energy consumption during this 28-year period: the US 40.2 percent, Japan 10.5 percent and China 10.5 percent. However, while the US and Japan have been growing at 2.1 and 2.6 percent per annum during the last decade, respectively, China is doing so at 7.0 percent per annum, with considerable room for growth if per capita energy consumption is taken into account (see Table 6).

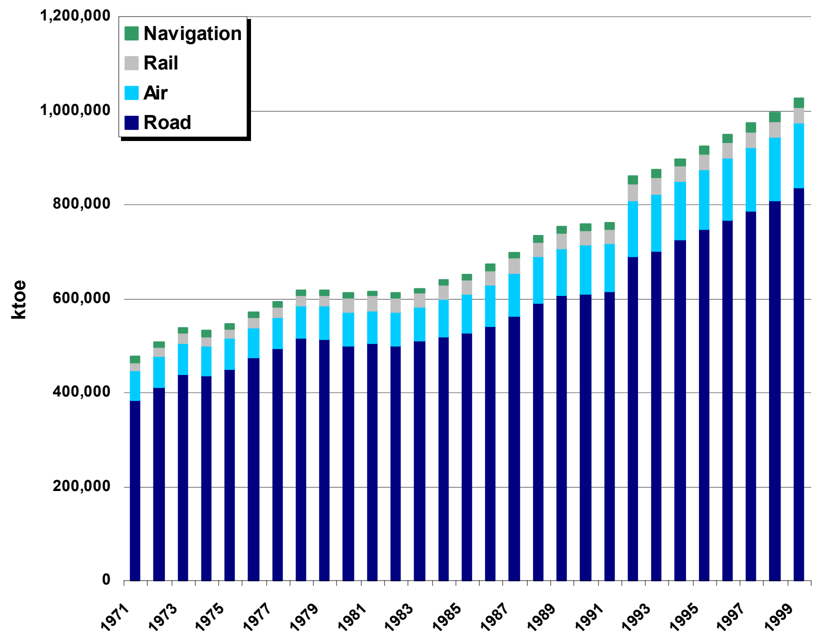
Table 6 Transport energy consumption and related statistics in APEC economies

Economy	Transport energy per capita (1999) (toe/capita)	Vehicles per capita[1] (1999) (vehicles/1000 inhabitants)	Cars per capita (1999) (cars/1000 inhabitants)
Australia	1.44	639.6	514.1
Brunei Darussalam	1.02	589.7	532.2
Canada[2]	1.59	400.9	355.7
Chile	0.39	138.8	88.1
China	0.05	36.8	5.5
Hong Kong, China[2]	1.16	78.4	57.8
Indonesia	0.10	25.1	14.0
Japan[2]	0.74	561.3	394.7
Korea[2]	0.59	281.8	163.3
Malaysia[2]	0.50	412.1	158.6
Mexico[2]	0.38	145.8	98.5
New Zealand[2]	1.27	606.3	485.7
Papua New Guinea	0.05	3.5	1.9
Peru[2]	0.13	41.6	26.0
Philippines	0.06	27.4	10.8
Russia[3, 4]	0.33	153.1	119.8
Singapore[5]	1.11	146.3	104.3
Chinese Taipei	0.60	738.6	232.5
Thailand	0.29	320.9	88.9
USA[5]	2.14	769.5	483.7
Viet Nam	0.06		
APEC	**0.41**	**187.7**	**108.7**

Notes: 1: Vehicles includes all passenger cars, buses, trucks and motorcycles (when available).
2: Figures for vehicles and cars per capita are for 1998.
3: Figures for vehicles and cars per capita are for 1997.
4: Figure for transport energy consumption is for 1992 and not for 1990.
5: Figures for vehicles and cars per capita are for 1996.

Source: IEA (2001a, 2001b) and national sources.

Figure 11 Transport energy consumption in the APEC region by mode



Note: The discontinuity in 1992 is due to the inclusion of Russia.

Source: IEA (2001a, 2001b).

REFERENCE CASE ASSUMPTIONS FOR TRANSPORT

The major considerations and assumptions for the reference case are the following:

- Energy consumption was calculated through econometric regressions, modified by known policies and developments in each economy.
- Infrastructure expansion plans for roads, airports, rail (including subways) and ports known to date are carried out according to announced schedules.
- Airport and port infrastructure keeps pace with projected demand.
- Vehicle ownership levels and compositions of fleets follow historic trends.
- Targets for alternative fuel consumption (natural gas, liquefied petroleum gas and ethanol for blending with gasoline) proceed according to government plans, except in Russia, where a less ambitious target was set for LPG.
- Plans for alternative-fuelled vehicles (such as in China and Korea) progress according to schedule.
- No new fuel economy standards are adopted apart from those already announced.
- Current trends in freight transport are maintained.
- Hybrid and fuel cell vehicles are introduced in most high-income APEC economies, though by 2020 they still do not represent a major share of the stock. Fuel cell cars are commercialised after 2010. Hydrogen for fuel cell cars is obtained from gasoline reformed on-board, while that for buses is obtained from natural gas.
- Tax credits and incentives in Japan and the US to promote the purchase of hybrid and fuel cell vehicles.

A wide range of specific assumptions and considerations was made for each APEC economy. For details, please see the documentation of the APEC Energy Demand and Supply Outlook 2002.

As shown in Table 7, technology offers considerable room for improvement in vehicle fuel economy. However, it is well-known that customers' preference for bigger and more powerful vehicles, especially in North America, has offset much of the efficiency improvements. Typical examples of this trend are sport utility vehicles (SUV), which have increased their share to a significant percentage of new vehicle sales. However, the rise in share of SUVs is not expected to continue indefinitely, as the recent increase in crossover vehicle sales is suggesting. Moreover, some economies – notably Japan – are experiencing a rise in the share of small and medium-sized cars.

Table 7 Technological options for improving light-duty vehicle fuel economy

Technology type	Fuel economy improvement[1]
Load reduction	
Mass (material substitution)	10% - 40%
Aerodynamics	4% - 10%
Other	4% - 8%
Conventional powertrain	
Variable valve control	10% - 12%
Other PFI spark ignition refinements	5% - 10%
Direct injection spark ignition	10% - 20%
DI compression ignition (DICI/diesel)	20% - 30%
Transmission	7% - 14%
Advanced powertrain	
Hybrid drive	30% - 60%
Fuel cell	50% - 70%
TOTALS (adjusted for interactions)	
Mid Term (2010 – 2015)	33% - 75%
Long Term (2020 – 2030)	100% - 260%

Note: 1: Relative to an average mid-1990s US light-duty vehicle rated at 25 mpg (9.4 l/100 km).

Source: DeCicco (2000).

Actual values for fuel economy improvements used in the reference case were more modest than those shown in Table 7. It is well-known that the real market potential is a fraction of the economic and technical potentials. Put plainly, fuel efficiency does not rank as a priority in the minds of users when deciding which vehicle to buy. Estimates for fuel efficiency improvement values used in the reference case also considered the particular characteristics of the vehicle stock in each economy (such as composition, age and turnover) and the estimated effects of enacted fuel efficiency standards.

For fuel cell cars, fuel economy assumptions were based on the results of the report *Bringing Fuel Cells to Market: Scenarios and Challenges with Fuel Alternatives*, commissioned by the California Fuel Cell Partnership. These are summarised in the table below.

Table 8 Estimated fuel economy of fuel cell cars

Type	Fuel economy km/l (mpeg)
Hydrogen	32 – 41 (76 – 96)
Methanol	26 – 31 (62 – 72)
Ethanol	24 – 27 (56 – 63)
Gasoline	24 – 27 (56 – 63)

Note: Fuel economy in km per equivalent litres and miles per equivalent gallons.

Source: California Fuel Cell Partnership (2001).

TRANSPORT DEMAND FORECAST – REFERENCE CASE

Transport is forecast to be the fastest-growing end-use sector in the APEC region, and will account for 72 percent of incremental oil demand during 1999-2020. Energy consumption is estimated to reach 1,824 Mtoe by 2020, an increase of 76.1 percent or 2.7 percent per annum over the 1999 level. This rate is slightly higher than in 1980-99, which reached 2.5 percent per annum on average (excluding Russia). Table 9 presents an overview of historical and forecast energy consumption in the transport sector, by income grouping and economy, over the period 1980-2020.

Though Group A will continue to account for the majority of APEC's transport energy consumption during the forecast period, its share will fall from 75.7 percent to 65.4 percent. The biggest increase in share will be by Group C, which will grow from 16.4 to 24.0 percent during the same period. Group B will also increase its share, albeit by a smaller amount, from 7.9 to 10.7 percent.

Oil products will continue to account for most of the energy consumed by the transport sector during the forecast period. Their share will fall slightly from 98.5 percent in 1999 to 98.4 percent in 2020. This is due to a rising trend of substituting oil products with alternative fuels such as natural gas and ethanol (used for blending with gasoline) due to environmental and energy security concerns, as well as an increase in the use of electricity in railroads and subways. Natural gas is expected to increase its share from 0.05 percent in 1999 to 0.29 percent by 2020. The share of electricity is forecast to fall from 0.74 to 0.65 percent during the same period. Coal is expected to have a negligible share by 2020, especially due to its phasing out in China during the first years of the forecast period.

Energy consumption in road transport is projected to increase at an annual rate of 2.5 percent during the forecast period, slightly below the average for the sector. Thus, its share of total transport energy consumption is expected to decrease from 81 percent in 1999 to 78 percent by 2020. Air transport is expected to account for this difference, as its share is forecast to increase from 13 to 16 percent during the period. Energy consumption in the air transport sub-sector is projected to increase at an annual rate of 3.5 percent. Marine transport is forecast to have the fastest growth rate among transport modes, at 4.2 percent per annum, reaching a three percent share in total transport energy consumption by 2020. This growth will take place mainly in Asia. Energy consumption in rail transport is expected to decline in 1999-2005, recovering after that, resulting in an average growth of 2.8 percent for the whole period. By 2020, rail will account for approximately three percent of transport energy consumption. Of incremental energy demand during the forecast period, road transport will account for 73.5 percent, air 18.9 percent, marine 4.3 percent and rail 3.3 percent.

Table 9 Transport sector energy consumption by income grouping and economy – reference case

	Energy consumption (Mtoe)					Annual growth (%)			
	1980	1990	1999	2010	2020	1980-1990	1990-1999	1999-2010	2010-2020
Group A									
AUS	17.7	22.7	27.1	34.9	43.7	2.5	2.0	2.3	2.3
BD	0.1	0.2	0.3	0.5	0.8	5.2	4.7	3.9	4.3
CDA	43.1	41.1	48.4	58.2	68.0	-0.5	1.8	1.7	1.6
HKC	1.6	3.4	7.8	13.7	18.1	7.6	9.8	5.3	2.8
JPN	55.5	74.3	93.6	108.1	120.4	3.0	2.6	1.3	1.1
NZ	2.5	3.5	4.8	6.1	7.6	3.6	3.4	2.2	2.2
SIN	1.9	3.3	4.4	5.7	6.6	5.8	3.4	2.4	1.5
CT	3.5	7.5	13.3	18.7	23.6	8.0	6.5	3.1	2.4
USA	418.2	486.6	584.2	740.7	903.0	1.5	2.1	2.2	2.0
Subtotal	*544.1*	*642.6*	*783.9*	*986.6*	*1,191.8*	*1.7*	*2.2*	*2.1*	*1.9*
Group B									
CHL	2.3	3.2	5.9	10.1	17.3	3.3	7.2	5.0	5.5
ROK	5.1	14.9	27.7	55.9	82.1	11.4	7.1	6.6	3.9
MAS	2.5	5.5	11.4	21.4	31.2	8.4	8.4	5.9	3.8
MEX	24.4	31.4	36.4	53.0	63.7	2.6	1.6	3.5	1.9
Subtotal	*34.2*	*55.0*	*81.4*	*140.4*	*194.3*	*4.9*	*4.5*	*5.1*	*3.3*
Group C									
PRC	24.5	37.4	69.0	119.5	204.9	4.3	7.0	5.1	5.5
INA	6.2	11.4	19.9	35.2	56.8	6.3	6.4	5.3	4.9
PNG	0.2	0.2	0.3	0.2	0.3	-0.1	2.6	-0.8	0.9
PE	2.6	2.6	3.4	4.7	6.4	0.2	2.9	3.0	3.1
RP	1.9	2.7	4.6	7.8	11.9	3.2	6.3	4.9	4.3
THA	4.0	10.9	18.2	28.1	46.2	10.5	5.9	4.0	5.1
RUS		81.8	50.3	66.4	87.9		-6.7	2.6	2.8
VN	0.6	1.4	4.5	12.1	23.6	8.4	13.4	9.4	6.9
Subtotal	*40.1*	*148.4*	*170.0*	*273.6*	*437.5*	*14.0*	*1.5*	*4.4*	*4.8*
APEC		**846.0**	**1,035.5**	**1,401.0**	**1,824.0**		**2.3**	**2.8**	**2.7**

Note: The 1990 figures for Russia correspond to 1992.
Source: APERC (2002a).

The results of the reference case highlight several issues, including oil dependency,[4] the relevance of the transport sector in future efforts to reduce CO_2 emissions, rapid growth of transport energy consumption in developing economies, and the growth in air transport.

In spite of energy diversification efforts by many economies – mainly through promotion of natural gas, ethanol and electricity consumption – the share of oil products by 2020 will remain practically unchanged from its 1999 value, and will still account for almost all energy consumption in APEC's transport sector (98.4 percent). This reflects the considerable inertia of the system and highlights the breadth of the effort to reduce transport's oil dependency. The latter is especially relevant to the challenges that construction of a hydrogen-based transport system will face.

APEC's transport sector is expected to increase its share of total final energy consumption to 30.7 percent by 2020, up from 27.5 percent in 1999. Moreover, transport is forecast to account for almost three-quarters of incremental oil demand during that period. Hence, this sector will be increasingly targeted in efforts to reduce GHG emissions. However, most GHG-related measures may not take place until after the reduction potentials of other sectors have been exhausted. This is because – as argued in an IEA study[5] – the implicit monetary value of the carbon used in transport fuels is higher than in other sectors.

The rapid growth of transport energy consumption in developing economies is due to several factors, including rising incomes and urban sprawl. These in turn drive rising levels of motorisation (vehicles per capita) and vehicle use (vehicle-km), and a shift to more energy-intensive modes (from non-motorised to public transport or two-wheelers, and later from these to cars and increased air travel). In many Asian economies, it must be noted that a significant proportion of vehicles are not personal-use cars but rather two-wheelers, taxis and other vehicles used for public transport. In this regard, the need fulfilled by paratransit or intermediate public transport (IPT), especially in Asia, should not be overlooked by policy-makers.

Air transport is one of the fastest-growing modes in every APEC economy. Though it still accounts for less than one-fifth of transport energy consumption in the APEC region, its increasing importance and impact will probably make it a target for policy-makers in the coming decades. This is already starting to happen, for example with the EU proposal to abolish the tax exemption for aviation fuel.[6] Rising incomes and cost reductions have been powerful drivers behind the rise in passenger travel. However, equally important, especially in relation to air freight transport, is the integration of world markets, differences in production costs among economies, and consumer demand.

Though the regressions used in the reference case did not distinguish explicitly between freight and passenger road transport, it can be easily deduced that the share of freight transported by truck is increasing in many economies, instead of or at the expense of less energy-intensive modes. Again, this is the result of several underlying trends and characteristics of production and distribution systems, which will make it difficult for transport companies to accommodate the requests of policy-makers regarding modal shifts.

The consumption figures in Table 9 and the above trends have very tangible impacts in the daily lives of the people in APEC. Though the focus of the reference case was to quantify future energy consumption levels, it is obvious that the most serious impacts are related to congestion, accidents and environmental degradation. Most of the trends and impacts are leading towards less, not more, sustainable systems. It seems that, put in economic terms, there is a serious failure in the transport system, whereby users are not paying the full cost incurred by its use. Some studies have

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4 For a discussion of APEC's oil dependency, please see the APERC reports *Emergency Oil Stocks and Energy Security in the APEC Region* (2000), *Energy Security Initiative: Emergency Oil Stocks as an Option to Respond to Oil Supply Disruptions* (2002) and the forthcoming study *Energy Security Initiative: Some Aspects of Oil Security* (2003).

5 IEA (1997).

6 For a debate on this issue, see for example http://www.globalpolicy.org/socecon/glotax/aviation/index.htm.

estimated that external costs are a significant percentage of internal costs.[7] This is a key area for policy-makers.

ENERGY SUPPLY

A key assumption of the outlook reference case produced by APERC is that growth in demand for energy will be met, or in other words there will be no serious supply constraints.

According to the results of the APEC 2002 Outlook, total primary energy supply (TPES) in the APEC region is expected to grow from 5,659 Mtoe in 1999 to 8,777 Mtoe in 2020, with an annual growth rate of 2.1 percent

The following sections review the outlook for the supply of oil, coal, natural gas, nuclear and renewable energies, both in APEC[8] and in the rest of the world.[9]

OIL

Over the forecast period, oil supply in APEC is projected to grow from 2,023 Mtoe in 1999 to 3,107 Mtoe in 2020, an annual growth rate of 2.1 percent. Oil is expected to maintain the highest share in total primary energy supply at around 36 percent (1999-2020).

The oil import dependency of APEC is projected to increase from 36 percent in 1999 to 54 percent in 2020. For APEC economies in Asia it will rise from an already high 61 percent in 1999 to 78 percent in 2020, most of which will be sourced from the Middle East. In other words, APEC Asia will become more vulnerable to oil supply disruptions.

World oil experts are generally agreed that sufficient proven oil reserves exist to satisfy projected demand during the next two decades. It also seems fairly certain that oil will retain its position as the single largest source of primary energy, given the lack of viable alternatives emerging to satisfy future transport energy demand within the timeframe of the next two decades. The IEA predicts that in 2020, oil production of 115 million barrels per day (mb/d) will represent 40 percent of the world's energy mix.[10]

Global proven reserves of oil, not including unconventional oil, are estimated at about one trillion barrels. According to IEA projections of global demand, some 730 billion barrels will be needed to satisfy cumulative oil demand for the years 2000 to 2020. This is not considered a major problem from the perspective of potentially diminishing reserves over this period, because over the last two decades of rapidly growing demand, reserve figures have actually steadily increased.[11]

Although there is controversy over the issue, the IEA states that global oil production need not peak in the next two decades, but this is dependent on the necessary investments being made and a better understanding of the way in which improved production technologies impact on field life. The medium and longer-term price of crude oil is considered to be the key to growth in reserve capacity and the ability of production to keep pace with growing demand. The price needs to be high enough to encourage active upstream investment in exploration and production capability, but not so high that demand and the economic health of consumers are adversely affected.

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7 For the average car, the Victoria Transport Policy Institute estimates that external costs are 32 percent of total costs (VTPI, 2002). Another study shows that in the EU plus Norway and Switzerland, external costs from transport were 8 percent of GDP in 1995 (Infras/IWW, 2000).

8 APERC (2002a).

9 IEA (2001c, 2002) and US DOE - EIA (2001).

10 IEA (2001c).

11 Ibid.

COAL

Coal is projected to maintain a 27 percent share in TPES of APEC. During the period 1999-2020 production is expected to grow at an annual rate of 2.1 percent. World coal reserves are vast and widely distributed. In the APEC region production is concentrated in the six economies with the largest reserves: Russia, USA, China, Australia, Canada and Indonesia. These six economies account for almost 99 percent of APEC's total coal reserves and production. Coal demand has increased substantially in recent years, a rise matched by increased production. However, APEC is expected to change from being a net coal exporter in 1999 to a marginal net importer of coal by 2020.

Most of the increase in coal demand will come from power generation, accounting for 83 percent of incremental growth. By region, China is expected to continue to be a major coal consumer in the APEC region, accounting for 41 percent of TPES for coal by 2020.

Rapid increases in the use of steam coal for power generation have been driven by the price competitiveness of coal when compared to other fuels. The IEA in its *World Energy Outlook 2000*[12] suggests this trend will continue over the next two decades, with rapidly industrialising economies in Asia accounting for much of the increased coal consumption. According to this source, coal is likely to maintain its position as the world's largest source of electricity generation through 2020: "…its share in this sector has remained almost unchanged for about three decades and is projected to stay roughly the same until 2020."[13]

The only cloud on this horizon is the possibility that the increasingly serious impacts of coal consumption (both regional and global) will lead policy-makers to put in place policies and measures to limit coal use and encourage a switch to alternative, cleaner forms of primary energy (including clean coal technologies).

NATURAL GAS

Natural gas is projected to constitute the third-largest part of TPES in APEC at around 22 percent over the forecast period. In the first half of the period it will experience faster growth at 2.8 percent per annum, followed by growth of 2.4 percent yearly in the second half. The Asian region, including Northeast Asia, Southeast Asia and China, is expected to see growth in natural gas demand of 4.6 percent per year. The current share of natural gas in TPES is low at eight percent compared with North America (24 percent), Latin America (19 percent) and Oceania (18 percent). Most of the growth in gas demand will come from the power sector. Rising per capita income combined with ease-of-use has been the key factor in its expansion. In future, technological development and environmental concerns will have a major influence on natural gas consumption.

Gas is an abundant energy source, and the cleanest of the fossil fuels. Reserves were 150 tcm at the end of 2000, and total recoverable resources are estimated at between 400 and 500 tcm, equivalent for up to 200 years of supply at current levels of consumption.[14]

As with crude oil, it can be argued that supply will not impose any particular constraints on regional demand over the next two decades. However, unlike oil, natural gas supply does have significant supply constraints, it must either be transported by pipeline or as LNG, both of which are expensive and affect the ability of gas to compete with alternative fuels. According to the IEA, "exploiting the world's gas resources will require massive investment in production facilities and infrastructure to transport the gas from the regions with large and low-cost reserves to highly populated areas with growing gas demand."[15] The share of transportation in total supply costs is a

12 IEA (2000).

13 IEA (2001c).

14 BP (2001).

15 IEA (2001c).

big factor in the natural gas supply equation, and this cost will rise as the reserves closest to markets are depleted. Given this situation, the LNG trade, which is almost exclusive to the APEC region, will likely expand dramatically.

The IEA argues that although advanced technologies have improved management practices and project design and productivity gains have reduced the costs of exploration, development and transportation, further advances are needed to reduce supply costs further and open up new supply options.[16]

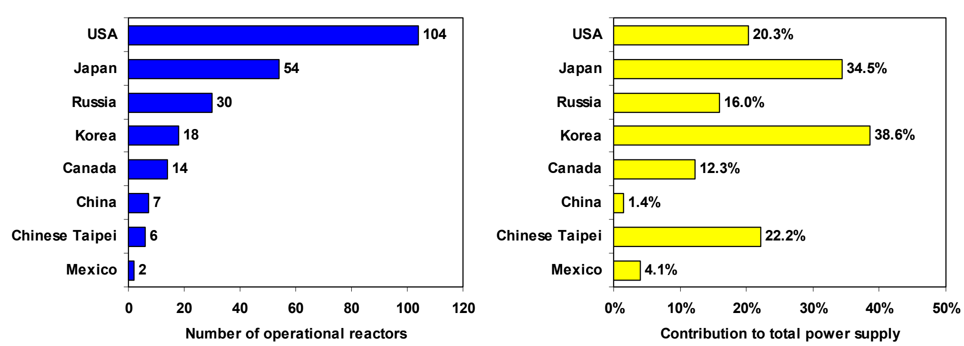
Natural gas has faced a number of hurdles in getting to the point where it could become the preferred fuel for power generation. Firstly, the wellhead price has historically been kept below true market levels in a number of economies (notably USA and China) for varying reasons, and regulations often prevented sale to power generators. Higher wellhead prices are needed in many locations to encourage the huge investment needed to get the gas to markets, but price at the city (or industry) gate must compete with very competitively priced coal and other fuels.

A lack of local markets has often impeded the development of gas reserves, especially where gas reticulation has not historically occurred.

NUCLEAR

Nuclear power accounted for around 17 percent of total global power generation in 1999, and for around 16 percent of net generation for APEC member economies. Figure 12 shows the number of nuclear power stations for each economy that has such technology, and also the share of nuclear in terms of power generated in the year 2002.

Figure 12 Number of nuclear power stations in the APEC region and their contribution to total power supply in 2002



Source: International Atomic Energy Agency, PRIS database.

Asia is one of the few regions in the world where nuclear power stations are actively under construction. The nuclear power stations currently under construction in APEC economies are as follows:[17] China - 4; Japan – 3; Korea – 2; Russia – 3; and Chinese Taipei – 2. With the availability factor of nuclear power plants generally increasing worldwide (from 72.9 percent in 1990 to 83.4 percent in 2001), the share of nuclear power has tended to increase slightly, even in the absence of new plants being commissioned.

Increased utilisation, combined with at least 14 new plants being commissioned within the next two decades in the APEC region, will see an increase in nuclear power output, estimated at 1.7

16 Ibid.

17 International Atomic Energy Agency, PRIS database.

percent per year. Northeast Asia (Japan, Korea and Chinese Taipei) will contribute 70 percent of total incremental growth (1999-2020) to meet the rising electricity demand. By contrast, North America will see a decline in nuclear power of 0.3 percent per annum as a result of the retirement of existing reactors. For the next two decades, the share of nuclear energy in TPES of APEC is expected to decline slightly from 6.7 percent in 1999 to 6.1 percent in 2020. This decline could be more pronounced if the pace of construction of nuclear plants falls significantly in the face of increasing public resistance to this technology.

HYDROELECTRICITY AND OTHER RENEWABLES

Hydroelectricity shows the fastest growth in TPES of APEC at 2.7 percent per annum (1999-2020), though its share is expected to be low at two percent for the entire forecast period.

Over the coming two decades, non-hydro new and renewable energy (NRE) in APEC is expected to grow at 1.1 percent per annum, which is lower than the annual growth rate of TPES at 2.1 percent per annum. The share of NRE is expected to fall from 8.4 percent in 1999 to 6.8 percent in 2020 due to a shift to commercial fuel sources as a result of socio-economic development.

Developed APEC economies will see little growth in large-scale hydro and geothermal, the traditional forms of renewable energy, and the potential of these technologies to make major contributions to secondary energy supply in developing APEC economies is limited to a relatively small number of economies with good water and hydrothermal resources. Endowed with the largest potential for hydroelectricity, China will see the fastest annual growth of 6.9 percent, accounting for around 70 percent of the total incremental growth of hydroelectricity in APEC.

New renewable technologies, such as wind and solar have considerable potential for growth, but from a very small base, and they are still emerging technologies facing all the hurdles that such technologies encounter before they become mainstream.

On the assumption that appropriate policies and measures are enacted, the IEA's *World Energy Outlook 2000* suggests that non-hydro renewables will be the fastest growing primary energy source in the world energy mix, with an annual growth rate averaging 2.8 percent over the period to 2020. However, due to the small base from which this expansion begins, the share of renewables would reach only 3 percent of primary energy by 2020 from the current 2 percent share worldwide. Most renewables will be used in the power generation sector of IEA/OECD countries. Preliminary analysis of the market impacts of planned policy changes supporting renewables in OECD countries indicates more dramatic growth of 8.6 percent per annum.[18]

[18] IEA (2001d).

CHAPTER 3

AN ALTERNATIVE SCENARIO - CONSTRAINTS AND OPPORTUNITIES

"The constraints on the energy system over the next 50 years will not be due to depletion of fossil fuel reserves, but rather to the environmental, social and geopolitical issues raised by energy production and consumption patterns."

Mr Kofi Anan, Implementing Agenda 21: Report of the Secretary General, UN Economic and Social Council, December 2001.

ENVIRONMENTAL CONSTRAINTS

The consumption of energy has significant environmental impacts. These relate to extraction, transport and combustion, and occur on local, regional and global scales. The issues associated with the local and regional areas include acid rain, air and water quality and the use and degradation of local resources. On a global scale the major issues involve the impact of human-induced climate change, the equitable sharing of finite resources and the need for developing economies to improve their standard of living.

Environmental integrity is a more challenging issue for developing economies with high rates of industrialisation and comparatively lax environmental standards. However, environmental attributes are increasing their prominence in the planning and implementation of energy programmes and projects in these economies. A number have already put forward regulatory measures in relation to the siting of power plants, the type of coal to be used, and the control of air pollution from power stations. This trend is expected to continue as environmental constraints are tightened in response to domestic pressures, and to environmental requirements imposed by aid donors and international financial institutions.[19]

Researchers have established for the first time that long-term exposure to fine particles of air pollution from coal-fired power plants, factories and automobiles can greatly increase an individual's risk of dying from lung cancer or heart disease.[20] According to the study, people living in heavily polluted urban areas are 16 percent more at risk than people in less polluted areas.

In the US, power plants built before 1980 generate about half of the electricity, but nearly all of the utility industry's sulphur dioxide, NO_x and soot. Although pollution levels have declined significantly in the US over the last two decades due to increased enforcement of state and federal clean air regulations, fine particle concentrations in urban air in major cities often still exceed limits set by the Environmental Protection Agency.

China has a much more challenging urban air pollution problem. China relies heavily on coal as an energy source, and the economy is now the world's largest emitter of sulphur (20 million tonnes in 2000), ahead of the US, Europe and former Soviet Union. A vast region (the densely populated southeast) has precipitation with pH 5.6 or lower, meaning a large area (around 30

19 ABARE (2002).

20 Arden Pope III *et al* (2002).

percent of the total territorial area of China) is affected by acid rain.[21] Particulate matter is another major urban pollutant. According to the World Resources Institute, China's six largest cities − Beijing, Shenyang, Chongqing, Shanghai, Xian and Guangzhou − ranked among the most polluted in the world in 2000.[22]

The Chinese government has recognised the cost to the environment resulting from a heavy reliance on coal, and is in the process of putting stricter air quality regulations into force, reducing consumption of the lowest grade coals, and introducing cleaner coal burning practices and technologies. Measures outlined in the most recent five-year plan include development of high-grade coal resources, exploration for oil and natural gas resources, promotion of oil and gas imports, exploitation of available renewable energy resources, encouragement of energy efficiency practices and technologies, and construction of a unified national power network.[23]

It is clear that the Asia-Pacific region stands at a crucial point in history. Demand- and supply-side technologies exist in the developed world to allow continued economic and social development in a way that would not cause the large-scale environmental impacts now emerging in some places, where rapid economic expansion has been accompanied by serious environmental degradation caused by the extraction and combustion of fossil fuels. If the ongoing trend of energy sector reform to improve the economic efficiency of electricity markets and the transfer of technologies between developed and developing countries can be harnessed, the potential exists for rapidly developing economies to leapfrog the traditional development pathway and pursue a more sustainable future.

As of December 2002, the entry into force of the Kyoto Protocol was pending on its ratification by Russia. This study assumes that it will do so in 2003, or sometime after the election of the new parliament in December of that year. Anyhow, the switching of fuels and the introduction of new technologies in the alternative scenario is at least partly based on the assumption that practical market-based mechanisms – in particular the Clean Development Mechanism (CDM) – will assist APEC economies in the delivery of sustainable energy while contributing to the abatement of greenhouse gases.

Under the Climate Change Convention, the Kyoto Protocol made provision for a number of 'flexibility mechanisms'. These are emissions trading, Joint Implementation (JI) and the Clean Development Mechanism, and are designed to assist Annex I Parties in meeting their targets.

The mechanism with the most potential to alter the energy supply mix in APEC economies in the short term is the CDM. This is defined in Article 12 of the Kyoto Protocol:[24]

> *The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.*

Currently (prior to the existence of any international emission trading regime) the CDM and the Global Environment Facility (GEF) are the only means by which developing countries can play a specific role in climate change prevention. The CDM allows for developed country Parties to engage in collaborative greenhouse gas mitigation activities with developing countries. It provides sustainable development for the developing countries while generating certified emission reductions that developed countries may use to meet their reduction commitments.

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21 Zhou (2002).

22 WRI (2000).

23 http://www.chinadaily.com.

24 http://www.unfccc.int.

At COP 6 bis, ministers decided to facilitate a prompt start for the CDM and invited nominations for membership of the CDM executive board at COP 7. The prompt-start CDM caters for projects submitted prior to the entry-into-force of the Protocol. The GEF provides developing countries with the 'new and additional financial resources' necessary to cover the cost of the steps they might be required to take (Climate Convention, Article 4.3), and has become the financial mechanism of the Convention.

EMERGING ENERGY SUPPLY PARADIGMS

If one looks back two decades, it is clear that major changes have occurred worldwide in many sectors – in terms of the technologies that have become industry standards, the way governments interact with sectors through policies and the regulatory environment, and the way in which consumers access and use services.

Although people have experienced major changes in their lives over this time period, they probably perceive the changes as occurring primarily in the way in which information is provided and disseminated, or in an array of new consumer products and services. When it comes to transport, and in particular the provision of electricity, the image is probably of cosmetic updates, but no fundamental changes in the supporting technologies.

We still drive cars powered by internal combustion engines running on petroleum products, we still get our electricity from utilities that operate large-scale baseload power stations and transport the electrons through transmission and distribution lines. Consumers are aware of attempts by governments to deregulate and/or privatise the power supply industry, usually when the promised reductions in electricity tariffs don't materialise or when something goes drastically wrong.

However, experts are aware that fundamental changes have occurred in the electricity and transport sectors over the last two decades, and that even greater changes are emerging or are on the horizon within the next 20 years. For example, recent energy sector reforms occurring in many economies regionally and worldwide are beginning to open the way for major changes in the standard technologies employed to generate electricity, in the location of power generation units relative to centres of demand (meaning greater use of distributed power systems), and the array of services available to consumers.

Deregulation of the natural gas sector is beginning to dramatically increase electricity sector demand for gas in developed economies like the US, and will stimulate gas infrastructure development in Asia, mainly focused on demand in the power generation and industrial sectors rather than the residential and commercial sectors.

In the transport sector, vehicle technologies are changing radically, as in the longer term are the fuels vehicles will run on. One can envisage that by 2020, demand for hybrid and fuel cell powered cars in developed economies will be mainstream and comprising a substantial percentage of new vehicle sales.

In fact, it is time to begin recognising the emergence of a new paradigm in the energy supply business. This will revolve around the concept of distributed power systems, but may eventually lead to a convergence between the transport and electricity supply industries.

For example, experts are now beginning to talk seriously about the idea of the V2G (Vehicle to Grid) concept. A recent study[25] has demonstrated how the newly emerging types of 'electric-drive vehicles' (EDVs) − the battery, hybrid and fuel cell vehicles – could play a potential role as utility resources. The idea has been made possible by electricity sector reform and by the development of sophisticated but affordable power metering systems. The idea relies on the ability of consumers to

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25 Letendre and Kempton (2002).

be able to plug their vehicles into the electricity grid when not in use. Although consumers will wish to plug their electric vehicles into the grid in order to recharge batteries or replenish their supply of hydrogen fuel, they could also sell power to the grid. In all probability, such consumers would not be able to compete with baseload power stations, but could sell peak load power and provide spinning reserve and act as power regulation units.

Another paradigm shift is occurring in the natural gas industry. The historical development path for natural gas in OECD countries has seen a relatively gradual transition from the 'town gas' era (when gas derived by reforming coal was reticulated to urban consumers), to the modern era where natural gas is widely available to consumers from all sectors. Because the reticulation infrastructure and mass market existed, it was relatively easy to replace coal gas with natural gas, to expand industrial consumption, and then finally to encourage investors to build gas-fired power stations, especially once high efficiency combined cycle gas turbines became available and restrictions preventing this use were removed.

Asia generally lacks gas reticulation infrastructure, and instead of following a traditional development path, moved straight to a modern technology model through development of electricity grid infrastructure. The development of natural gas infrastructure is a very recent event in Asia, and hence is still in a very immature state of development in most economies in the region.

For example, Japan, South Korea and Chinese Taipei have no significant gas resources and are not easily accessible by pipeline. Japan began importing natural gas as LNG in 1970, South Korea in 1986, and Chinese Taipei in 1990. All three have developed 'city gas' infrastructure and markets, but Japan still lacks a nationwide gas transmission network. The market development pattern centres on individual LNG import terminals and reticulation lines from each port.

Even Asian economies with reserves of gas have relatively poorly developed natural gas infrastructure systems, and the pattern of consumption differs markedly from that in Europe and the US. Residential and commercial consumer markets in almost all gas-producing Asian economies are essentially non-existent. Power generation plants account for most natural gas demand, and there is a small amount of industrial consumption.

Despite this, the prospects for growth in Asian gas demand are very promising.[26]

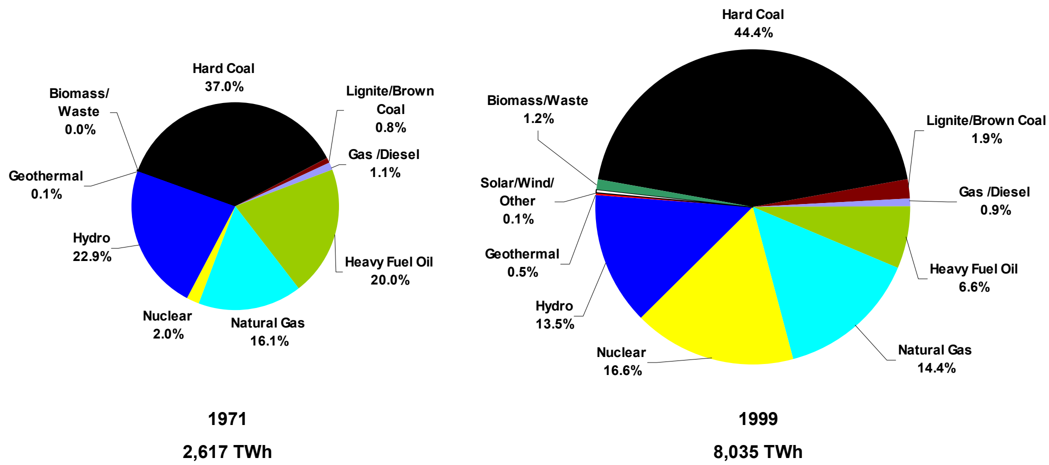
FUEL SUPPLY AND DEMAND CONSIDERATIONS

OIL

If one looks back over the last two decades, the overall importance of crude oil as a key fossil fuel resource has remained, but the demand pattern has changed significantly, especially with respect to oil consumption for power generation. Prior to the 1970s oil crises, heavy fuel oil was one of the main fuels used for power generation, oil-fired plants providing 20 percent of total generation (see Figure 13). In 1999, the share of oil-fired generation had declined to 6.6 percent of the total, although the absolute amount of power generated using oil has remained virtually unchanged.

26 Dixon (2002).

Figure 13 Breakdown of fuels used for APEC power generation in 1971 and 1999



Source: IEA (2001a, 2001b).

In the power generation sector, petroleum products are used mainly today to provide mid-peaking load power, to provide power to remote locations, and as backup.

Figure 14 shows consumption of oil in APEC economies in 1999, broken down into amount of primary oil supply and the percentage used to generate electricity. Oil-fired power generation has been a traditional practice in many Asian economies in particular. Before 1973, oil was relatively cheap, as well as widely available. The 1973 oil embargo and subsequent price peaks proved to be very important in stimulating the idea of fuel diversification as one means of ensuring security of energy supplies.

This change in thinking has, in turn, stimulated the exploration for and exploitation of natural gas in Asia (discussed further below).

Figure 15 shows a similar breakdown for transport consumption as a percentage of the total. While a substantial amount of crude oil is consumed outside the transport sector, the share of oil in transport-sector fuel consumption is almost 100 percent for all APEC economies. In other words, in the transport sector there is almost no fuel diversification 20 years after the oil shocks of the mid 1970s.

In looking out 20 years from now, three questions come into focus when thinking about oil: availability, price and acceptability.

Projections of future oil prices used in the APERC Outlook 2002 are in-line with the numbers considered in the IEA[27] and EIA[28] outlooks. The key conclusions are:

- Oil prices will stay below US$25 per barrel (at 1999 prices), excluding temporary price shocks;
- OPEC oil capacity and production will increase rapidly over the next two decades to unprecedented levels, and will more than double in the Middle East.

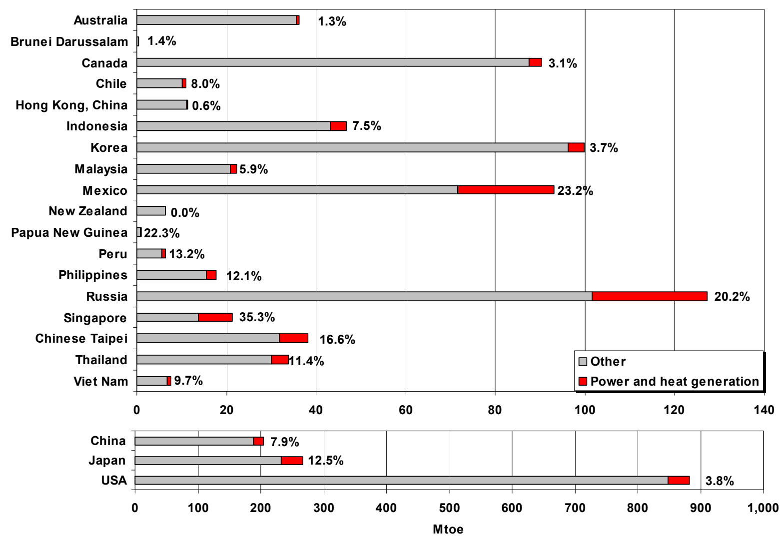
The assumptions underlying these forecasts have been questioned by at least one leading oil expert. Gately (2001)[29] argues that the models used to make such forecasts are internally

27 IEA (2000).

28 US DOE - EIA (2001).

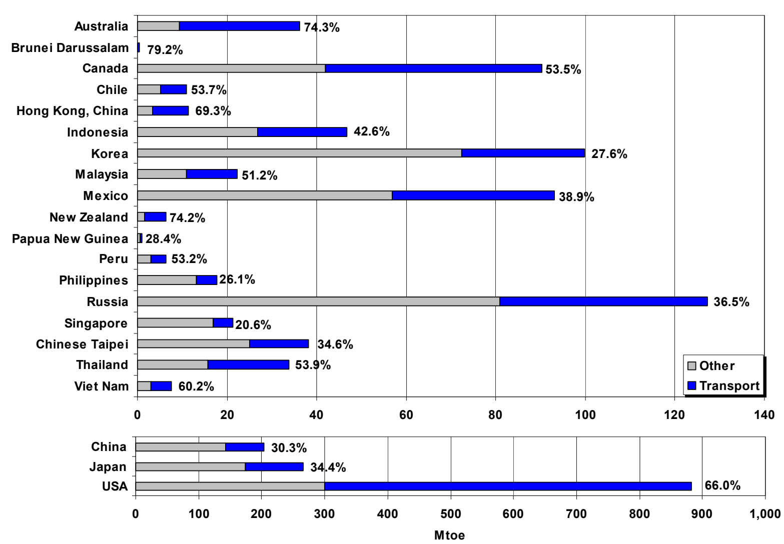
inconsistent. He points out that OPEC's productive capacity has not changed over the last 30 years, and that with surplus OPEC capacity now nearly used up, the likelihood of expansion in productive capacity being able to keep pace with demand in a timely manner is questionable.

Figure 14 Oil consumption in APEC economies in 1999 – amount used for power generation as a percentage of total primary consumption of oil



Source: IEA (2001a, 2001b).

Figure 15 Oil consumption in APEC economies in 1999 – amount used for transportation as a percentage of total primary consumption of oil



Source: IEA (2001a, 2001b).

29 Gately (2001).

His argument is that if the models accurately represent the price-responsiveness of world oil demand (assumed essentially inelastic), then both the Reference Case and the High Price Case in the US DOE report project oil prices in 2020 (around US$22 and US$28 respectively) that are far too low – because these cases rely on supply behaviour by Gulf producers that is not in their own self-interest.

In contrast to the assumption that OPEC will struggle to coordinate its actions sufficiently to influence prices, he postulates that even partial OPEC coordination to control the rate of expansion in production (especially by the core group of key producers: Saudi Arabia, Kuwait and the United Arab Emirates), could push prices towards US$30 per barrel by 2020. Gately argues that the loss of revenue would be more than offset by the lower production costs, and would leave these key producers with more reserves for the future.

In the recent publication *The Geopolitics of Energy into the 21st Century*[30] the authors discuss the dissenting view on oil availability into the future. Some experts argue (on the basis that 80 percent of the oil fields in current production were discovered before 1973), that by 2010 the supply of conventional oil will be unable to keep up with demand. It is also argued that although new technologies may appear to play a role in prolonging field life, they may be just leading to accelerated depletion by making extraction more efficient, but not necessarily leading to greater recovery rates. Further, it is argued that estimates of oil reserves are inflated by governments and companies for reasons that include a desire to increase their prestige and/or their ability to secure loans that use oil reserves as collateral.

Both the EIA and IEA forecasts treat the Persian Gulf as the residual source of supply, assuming that any supply gap would be filled by the high-reserve, low-cost producers in the Gulf. This contention actually lends weight to Gately's argument that a few key Gulf producers could force the price of oil up over time.

John Roberts, a consultant specialising in the inter-relationship between politics, energy and economic development, believes that although Gulf States may have expressed intentions to increase their production capacities over recent years, there is little evidence that they have the will or the means to do so.[31]

For example, since the first oil price crisis of 1973-74, OPEC production capacity has scarcely grown, and in terms of overall production the output of the six Gulf OPEC producers has actually fallen. Partly, this is due to the decision by OPEC members in the late 1970s and 1980s to constrain supplies and force up prices. However, with the loss of market share experienced by OPEC due to fuel switching and diversification of supply options, the cartel now seems to be in a position of trying to increase production to win back market share in the face of rapidly expanding demand in fast developing economies.

The Gulf States will face a number of challenges in attempting to expand production capabilities to meet growing global demand. The first is the capital required to affect major expansion of supply infrastructure. Almost all the Gulf States have failed to diversify their economies from the heavy reliance on oil, and their net incomes over the recent decade of low oil prices have suffered significantly. For example, Saudi Arabia's per capita GDP is now between one quarter and one fifth of the average level in the late 1970s.[32] This has led to public dissatisfaction with the ruling elite, and a lack of liquid capital to fund needed future oil production growth. Saudi Arabia has a generous production over-capacity, so this is not an immediate problem, but a possible future one.

There is one school of thought that the Gulf producers will respond to increasing demand reactively, rather than pro-actively. This could put pressure on oil prices, ensuring they remain

30 CSIS (2000).

31 Roberts (2001).

32 Ibid.

firm. Over the long term, such an outcome could be good for both producers and consumers if it encourages diversification away from oil and encourages more efficient and cleaner technologies.

Zagar and Campbell argue that production of 'conventional' oil will peak in the next decade, and will begin to decline thereafter.[33] Their arguments are based on analysis of rates of discovery, estimations of the true resource base, and trends in production and demand. In their opinion, the stage is set for another 'energy crisis' starting with higher prices from Middle East control and followed by the onset of physical shortage by 2010.

The IEA assumes that oil demand over the next two decades will be met by: (1) increases in natural gas liquids, (2) increases in 'identified unconventional' oil to a maximum of 2.4 Mb/d by 2010, (3) increases in processing/refining liquids, and (4) increases in Middle East production rising from its current 18 to 45 Mb/d by 2020 – at which time it will be 62 percent of world production. The rest of the world meanwhile declines from its current 45 Mb/d to 27 Mb/d by 2020.

According to Zagar and Campbell, the IEA introduces a term referred to as a 'balancing item-unidentified unconventional' rising from zero in 2010 to 19 Mb/d by 2020. They go on to argue that this is not a credible hypothesis for a number of reasons:

- To meet the forecast demand increase to 2020, today's worldwide oil production would have to increase 55 percent. (Zagar and Campbell see this as an unreasonable assumption).
- The growing control of the market by the Middle East is considered inconsistent with US$25/b oil by the year 2020.
- It may be technically feasible for Middle East countries to increase production by 200 percent, but is counter to the interests of producers who want to maximise profits and may not be politically or economically realistic.
- Huge identified deposits of unconventional oil already exist, so the problem is not identification, but the likelihood that this level of production could be brought on-stream within that timeframe and at a competitive price.

Regardless of such arguments about the likely price of oil in 2020 − which is basically unknowable, but likely to be in the range US$10 to US$40 – the question is whether the future price is actually that important. If one looks at the true price of oil, apart from periodic spikes, it has remained relatively flat over the last two decades. The key driver of change in fuel purchasing strategies and surge in non-OPEC oil exploration has been the expectation of future prices, not the absolute price level.

The price of oil in 2020 may be US$25, but a number of important considerations, including another price/supply shock, could stimulate major changes in fuel consumption patterns as well as promote a number of emerging technologies, pushing them into mainstream consumer markets.

Another issue, and one not addressed in much detail by the supply/demand forecasts discussed above, is the question of the future acceptability of oil. Consumption of fossil fuels, in particular coal and oil, has substantial environmental and health impacts. These include the emission of smog forming pollutants such as NO_x and SO_x, as well as emissions of particulates and other harmful compounds.

Although pollutant emissions from vehicles in developed economies have actually declined over the last two decades because of the nearly universal requirement for catalytic converters and stricter fuel specifications,[34] there is still the question of greenhouse gas emissions. For the transport sector, this is a major policy issue because there are millions of small-scale mobile sources

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33 Zagar and Campbell (2000).

34 UNDP (2000).

and few clear technology options exist to radically reduce or eliminate greenhouse emissions from internal combustion engines running on petroleum products.

Mitchell *et al* in a recent publication believe oil is about to face an unprecedented series of challenges.[35] Because oil is a major polluter, they believe it will face increasingly stiff competition from other energy sources – gas and renewables – and more stringent regulation and control, with higher taxes. They argue that this is the reason why oil companies are now beginning to position themselves as energy industries.

In case the Kyoto Protocol is not ratified, if action to reduce greenhouse gases becomes imperative in the near future because of an increasing burden of evidence that anthropogenic emissions of greenhouse gases are detrimental to life on earth, then the delays that have occurred in making restrictions of GHG emissions effective will increase the severity of the measures that will eventually be needed to limit GHG concentrations in the atmosphere to any given level. The authors believe that activities during 2000-20 may track close to the 'conventional vision', but plans and investments made during this time will more and more need to follow the trend towards a different future.[36]

COAL

There is no denying that coal is plentiful and very cost competitive in Asian power markets, and could continue to provide a large percentage of the primary energy consumed by the electricity generation sector, and needed to underpin the rapid socio-economic development occurring regionally.

It is also clear that rapidly industrialising economies relying heavily on coal for power generation and other direct energy uses are bearing substantial environmental costs from this practice. This is especially true where low-grade coal is widely used, and where regulations do not provide adequate control over emissions.

In the IEA report *Towards a Sustainable Energy Future* it is argued that the coal-supply and price outlook will hinge on the effect of new environmental and climate change policies on demand prospects.[37] In an alternative supply and demand outlook scenario, it is certainly reasonable to argue that long-term demand will be affected by the likely introduction of environmental and climate change policies. Tightening of environmental policies is an ongoing process in developed APEC economies, but will gain importance in developing economies as the environmental impacts of burgeoning energy demand growth become increasingly difficult to ignore.

Growing demand for clean energy solutions will impact on the willingness of investors to put capital into further expansion of coal production capabilities on the one hand as importers look to cleaner fuels, but will also promote dissemination of clean coal power generation technologies.

Coal has a high carbon content, but clean coal technologies can lower the carbon emissions rate relative to current technologies, such as pulverised coal boilers. For example, a pulverised coal boiler operating at 34 percent efficiency has a carbon emission rate of 260 g/kWh, while an integrated coal gasification combined cycle (IGCC) facility operating at 42 percent efficiency produces 20 percent less carbon, or 210 g/kWh.

For every gigawatt hour (GWh) of electricity generated by IGCC, 50 tonnes of carbon could be avoided, compared with the emissions from a pulverised coal boiler. By 2020, advanced coal-fired

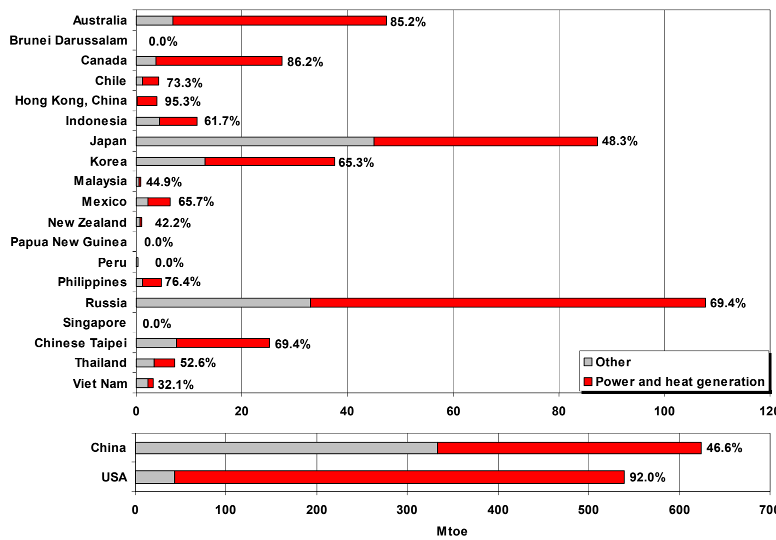
35 Mitchell, Morita and Stern (2001).

36 Ibid.

37 IEA (2001d).

plants may achieve 60 percent efficiency through R&D, reducing their carbon emission rate to 150 g/kWh, and saving 110 tonnes per GWh.[38]

Figure 16 Coal consumption in APEC economies in 1999 − amount used for power generation as a percentage of total primary consumption of coal



Source: IEA (2001a, 2001b).

Advanced clean coal power generation technologies such as IGCC are still at a pre-commercial stage of development, and so their capital and operating costs are still non-competitive and suffer a technology risk premium. There are three IGCC demonstration plants currently in operation or under construction in the US, so the rapid commercialisation and dissemination of such technology is still some way off.

Prof Zhou Fengqi in his presentation to the APERC 2002 Annual Conference,[39] stated that although coal will continue to be the main source of primary energy in China for many years to come, the installation of clean coal technologies will be a high priority. These include coal washing and widespread adoption of cyclic fluidised combustion process, as well as installation of flue gas processes to remove sulphur, nitrogen and particulate matter.

NATURAL GAS

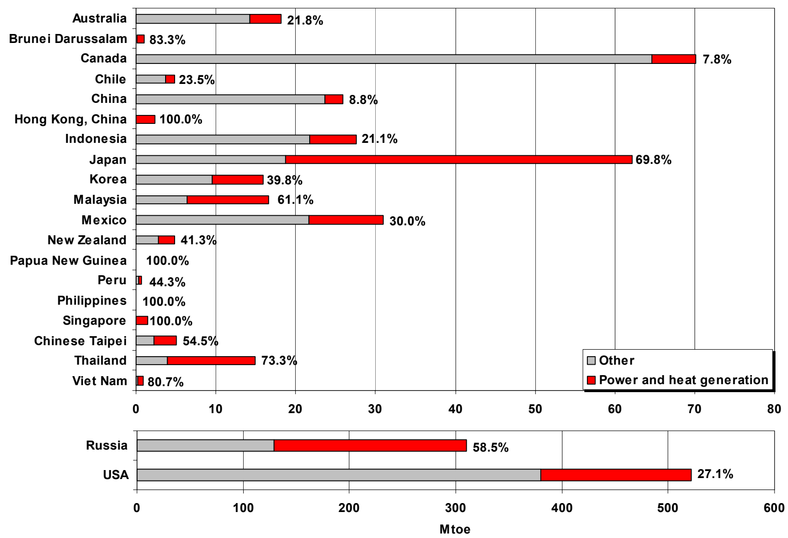
Although, as pointed out in the discussion above, the natural gas industry has a short history in Asia, demand is still modest, and gas infrastructure is relatively poorly developed, the natural gas industry is likely to play a pivotal role in the region in the near and medium term. Significant growth is also expected in Latin America.

Figure 17 shows natural gas consumption in APEC economies in 1999. Gas consumption in the power sector is currently growing strongly in most developed APEC economies, and is of particular importance to many Asian and Latin American economies.

38 US DOE (2000).

39 Zhou (2002).

Figure 17 Natural gas consumption in APEC economies in 1999 – amount used for power generation as a percentage of total primary consumption of gas



Source: IEA (2001a, 2001b).

The importance of the power sector as a key gas consumer in Asia is best illustrated by looking at a gas consumption breakdown for APEC economies, as shown in Table 10. For most Asia n economies, even those that are net importers of gas, power sector demand is very high – in many cases accounting for over 50 percent of supply. The exception is China, where natural gas used for electricity generation accounted for only 8.8 percent of total gas demand in 1999.

The natural gas industry in China is still at a very immature stage of development, and historically the fertiliser industry accounted for much of the consumption. However, now that the government is promoting the use of natural gas and engaging in active development of gas fields and pipelines, the pattern of consumption is likely to change significantly. Russia exports most of its gas production, while domestically more than half of consumption is in power and heat generation.

With well-developed gas markets and indigenous reserves, developed APEC economies such as Australia, Canada, New Zealand and the US tend to have a more diversified demand pattern across sectors. Transport sector demand is low almost universally, demonstrating the importance of oil with respect to that sector.

Demand in Asia is obviously driven by the power sector primarily, with industrial sector demand developing once basic supply infrastructure is established. Even in Indonesia and Malaysia, with abundant indigenous reserves, reticulation to residential and commercial consumers is almost non-existent currently.

The IEA believes that the development of gas-to-gas competition, driven by regulatory reform, will have a major impact on prices and on investment in upstream gas-supply projects. This will stimulate the development of short-term (spot) markets and hasten the de-coupling of gas and oil prices in long-term contracts. This could prove a very important trend if over the longer term natural gas consumption continues to grow very strongly but pressure is put on the price of oil for a variety of reasons.[40]

40 IEA (2001d).

Table 10 Gas consumption in APEC economies in 1999 (ktoe)

	Electricity		ResCom and agric		Transport		Industry and other		Total
Australia	3,981	21.8%	3,570	19.6%	54	0.3%	10,617	58.3%	18,222
Canada	5,479	7.8%	22,659	32.3%	54	0.1%	41,916	59.8%	70,108
New Zealand	1,986	41.3%	250	5.2%	8	0.2%	2,563	53.3%	4,809
USA	141,480	27.1%	181,003	34.7%	132	0.0%	198,696	38.1%	521,311
Japan	43,413	69.8%	13,276	21.4%	-	0.0%	5,472	8.8%	62,161
Korea	6,324	39.8%	7,182	45.2%	-	0.0%	2,391	15.0%	15,897
C. Taipei	2,734	54.5%	800	15.9%	-	0.0%	1,487	29.6%	5,021
Mexico	9,292	30.0%	796	2.6%	-	0.0%	20,863	67.4%	30,959
Chile	1,139	23.5%	271	5.6%	6	0.1%	3,425	70.7%	4,841
BD	819	83.3%	-	0.0%	-	0.0%	164	16.7%	983
HKC	2,389	100.0%	-	0.0%	-	0.0%	-	0.0%	2,389
Indonesia	5,831	21.1%	-	0.0%	-	0.0%	21,822	78.9%	27,653
Malaysia	10,141	61.1%	12	0.1%	-	0.0%	6,433	38.8%	16,586
PNG	137	100.0%	-	0.0%	-	0.0%	-	0.0%	137
Peru	286	44.3%	5	0.8%	-	0.0%	355	55.0%	646
Philippines	8	100.0%	-	0.0%	-	0.0%	-	0.0%	8
Singapore	1,417	100.0%	-	0.0%	-	0.0%	-	0.0%	1,417
Thailand	10,954	73.3%	-	0.0%	5	0.0%	3,975	26.6%	14,934
Viet Nam	743	80.7%	-	0.0%	-	0.0%	178	19.3%	921
Russia	181,148	58.5%	45,542	14.7%	174	0.1%	82,854	26.8%	309,718
China	2,278	8.8%	4,849	18.7%	31	0.1%	18,808	72.4%	25,966

Note: Electricity consumption includes combined heat and power. Industry and other includes feedstocks, non-energy related consumption and other transformation activities.

Source: IEA (2001a, 2001b).

Demand for natural gas is projected to grow strongly in the region, and it will be supplied by both pipelines and LNG. ASEAN economies have plans to develop a regional pipeline network linking major regional producers with major markets. This is a long-term dream, however, and faces daunting logistical and financial hurdles. Over the next two decades, LNG trade is likely to become much more deeply established regionally, especially now that new producers are entering the market and changing the basis on which the trade operates.

There are signs that the LNG market is becoming more flexible, as international trade grows and as downstream markets gradually open up to competition. Buyers are increasingly looking for short-term supply flexibility. In recent years, increasing volumes of LNG have been traded on the spot market, with trade flows changing in response to regional market factors. According to the IEA, "…continued growth in short-term LNG trading could spur a fundamental change in the way new LNG projects are structured. It may be possible in the future to finance gas field developments and liquefaction projects without tying all the capacity to long-term contracts as at present."[41]

Deutsche Bank research predicts that worldwide LNG demand will grow by 10 percent from 2000 to 2005, and that a 45 percent rise in US LNG demand is likely over the same period.[42]

The next major market for LNG will be China. The initial focal point of this emerging market will be the Guangdong import terminal. Imports are scheduled to commence with a three million tonne per annum contract, increasing to five million tonnes per annum by 2008 as Phase 2 proceeds. At least two other Chinese LNG projects are currently under consideration.[43]

One international expert in the LNG business envisages it is realistic to imagine at least four LNG terminals in full operation in China by 2020, each handling 20 million tonnes of LNG annually.[44]

Considering regional trends in production and trade over the next two decades, APERC projects that the dependence of Japan on gas imports from outside the region may fall, as rising Australian production satisfies the growing need for imported gas in this economy. Asia, currently a net exporting region, is projected to become a net importer in the second half of the projection period, supplied mainly from Australia, the Middle East and the FSU transition economies.

But LNG is no longer the fuel of choice just for isolated countries looking to diversify supply sources. In the last two years, LNG's flexibility has generated renewed interest from firms looking to profit from the gaping arbitrages emerging as global markets deregulate. So rapid is the growth in LNG demand that there is now concern that it has far outstripped supply, and that the lead-time for LNG shipping construction is choking its role in transforming markets.

NUCLEAR

Global growth in nuclear power capacity has slowed significantly over the last decade due to increasing concerns over nuclear plant safety and large capital and decommissioning cost requirements in liberalising energy markets.

Figure 18 shows worldwide growth in energy consumption from nuclear power for the period 1970 to 2000, with US Department of Energy projections to 2020. This analysis concludes that the potential of nuclear power to make a significant ongoing contribution to power production is constrained by the lack of enthusiasm from investors and the public concerning this technology.

However, increased energy security concerns and the need to comply with GHG emissions reductions may well extend the life of existing plants and spur investment in capacity additions. Japan, China and South Korea will account for over half of cumulative additions to global nuclear power capacity in the period to 2020, with India being the other country likely to significantly increase capacity.

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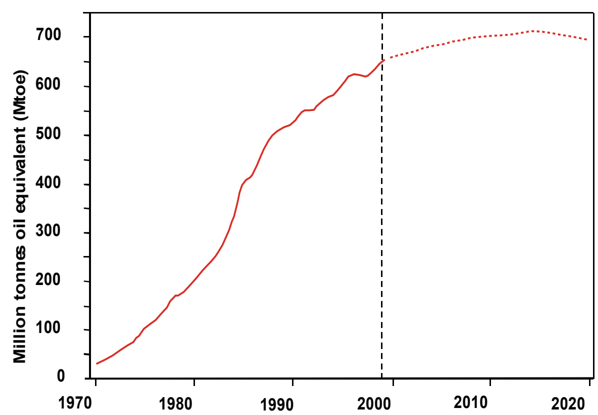
41 IEA (2001c).

42 *Asia Gas & Power* (2001).

43 Dixon (2002).

44 Pers comm. Dr David Nissen. Senior LNG Consultant with Poten & Partners, NY.

Figure 18 World nuclear energy consumption (1970-2020)



Source: Modified from diagram in US DOE - EIA (2001).[45]

RENEWABLES

Many energy forecasting experts believe that non-hydro renewables will be the fastest growing primary source in the world energy mix over the next two decades. The IEA forecasts an annual growth rate averaging 2.8 percent.[46] Growth rates for individual renewable technologies like wind power exceed this figure by a long way in countries where this technology is being actively promoted. However, as indicated earlier, due to the small base from which this expansion begins, the share of renewables will reach only three percent of primary energy supply by 2020 from the current two percent share worldwide.

Renewable resources are currently exploited in the power sector almost exclusively, but in the longer term may be used increasingly to supply transport energy. The key factors underpinning greatly expanded exploitation of renewable resources will be government policies and measures to curb pollution and greenhouse gas emissions, policies to diversify the energy mix and enhance security of supply, and cost reductions.

Although renewable energy has the technical potential to meet a large percentage of the region's future energy demand, and the resources are plentiful, most forms of renewables struggle to be competitive when their costs, as measured in today's markets, are compared with conventional energy sources.

In most markets in the region, newer renewable technologies will have to overcome significant hurdles before they are widely accepted as viable alternatives to fossil fuels on the scale needed to dramatically alter projected trends in fuel consumption. There is general agreement among experts that non-hydro renewables will require continuous and large-scale government support to gain widespread acceptance. After the Kyoto Protocol is eventually ratified by enough countries to make it binding, there will probably be a substantial boost to renewable forms of energy, at least in Annex B countries. If flexibility options such as the Clean Development Mechanism are also promoted strongly, then there is likely to be a flow-on effect to non-Annex B countries.

BIOENERGY

Bioenergy will continue to be a major energy source in developing economies over the next two decades. Although the overall level of demand will increase, its share of total primary energy

45 US DOE - EIA (2001).

46 IEA (2001d).

supply will fall as these economies move increasingly towards greater levels of electrification. One of the traditional forms of bioenergy consumption is use of firewood for cooking. This practice is frequently unsustainable and polluting, and so as supplies dwindle due to forest clearing, as people move to the urban areas and as electricity services spread, the domestic consumption of firewood will diminish in terms of contribution to total primary energy supply.

One trend that is likely to continue is the co-firing of biomass with coal in situations where the biomass is plentiful and costs low (such as when it is a by-product of agricultural practices). Such a process requires modifications or additions to the power plant, and is a retrofit option for existing coal plants to achieve a large-scale introduction of bioenergy in the power sector. The limit to the amount of bioenergy that can be co-fired is 10-15 percent. Solid bioenergy can be gasified prior to co-firing, raising the percentage that can be added.

Advanced bioenergy technologies include gasification and pyrolysis. Advanced technologies can achieve high conversion efficiencies. Bioenergy gasification technology converts solid bioenergy into a combustible gas through a partial oxidation process. The resulting gas can be of low or medium calorific content depending on the conditions of the gasification. The gas can be burned in a turbine, a fuel cell or an internal combustion engine. Gasification technology is at an early stage of commercialisation, with some companies already offering gasification units for direct co-firing applications.[47]

In pyrolysis, the fuel is heated in the absence of air to produce gas, oil and char. Fast pyrolysis techniques produce a higher proportion of the oil while slow pyrolysis makes char. The technology is now moving from the R&D to the commercialisation phase.

HYDROPOWER

The developed APEC economies have almost fully exploited their competitive large-scale hydro, and many developing economies have limited resources. Any increase in hydropower capacity over the next two decades is likely to come from a small number of developing economies, in particular China.

The downside of further large-scale hydro development is that such projects often have negative environmental and socio-economic effects.

GEOTHERMAL

The IEA WEO 2000 outlook[48] predicts that geothermal energy use will almost triple over the next 20 years. Almost all of this would occur in the Asia-Pacific Rim. However, once again, the resource base is limited and concentrated in a few economies.

WIND POWER

The IEA WEO 2000 predicts that worldwide demand for wind power will increase by nearly 13 percent a year over the next 20 years. Although much of this capacity will be installed in Europe, the growth of wind power in the APEC region should also be robust, with many economies having suitable wind resources.

Wind power could be in close competition with fossil fuels within the next decade in locations with very good wind conditions and under the assumption that current capital costs will decline further.

The high-growth markets for wind power are currently Western Europe and the US. According to the European Wind Energy Association (EWEA), installed capacity in Europe increased by around 40 percent per year from 1994 to 2000.[49] The EWEA has set a goal of 60,000

47 IEA (2001d).

48 IEA (2000).

49 EWEA (2001).

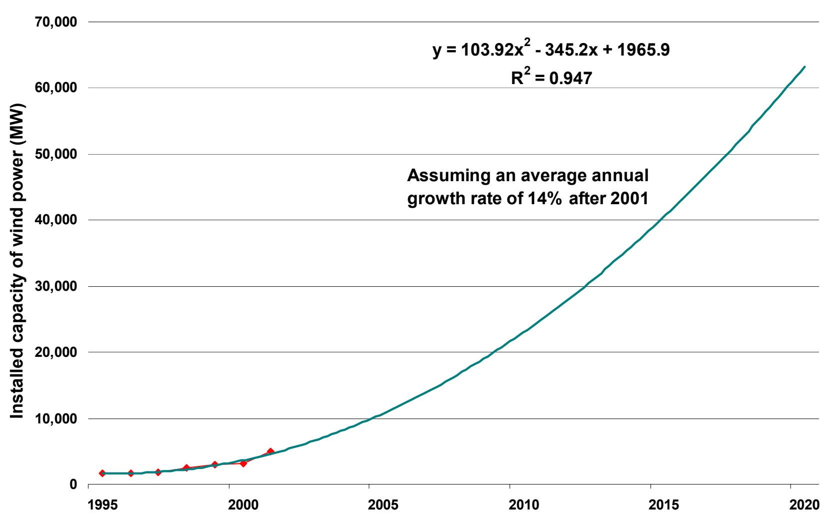
MW of installed capacity in Europe by 2010, and 150,000 MW by 2020. From the currently installed capacity, this goal would require average annual capacity increases of around 13 percent from 2000 to 2020, a projection that seems quite achievable given the increasing price competitiveness and environmental advantages of this technology.

Table 11 Installed wind power capacity in APEC economies (1995-2001)

	1995	1996	1997	1998	1999	2000	2001
	Installed capacity (MW)						
Australia			4	10	11	25	(50)
Canada	20	20	21	25	124	137	(141)
Chile							2
China	44	79	146	200	265	265	
Japan		14	21	38	83	83	115
New Zealand			4	4	35	35	35
USA	1,614	1,615	1,611	2,141	2,500	2,554	(4,554)
TOTAL	**1,678**	**1,728**	**1,807**	**2,418**	**3,018**	**3,099**	**4,897**

Note: The figures in parenthesis are estimates.
Source: Economy sources.

Figure 19 Possible growth scenario for installed APEC wind power



The European Wind Energy Association, in collaboration with the Forum for Energy and Development and Greenpeace International, recently published a report suggesting that it is conceivable that 10 percent of global electricity demand in 2010 could be met by wind power.[50]

The development scenario to achieve this goal requires 30 percent growth rates in annual wind power installations from 2004 to 2010, followed by declining rates thereafter. As the report points out, growth rates of 20-30 percent per annum are very high for an industry manufacturing heavy equipment. The wind industry is achieving this currently in the very early stages of its development,

50 EWEA *et al* (2001).

and the challenge will be the industry's ability to continue meeting demand through increased manufacturing capacity as the industry matures.

Among APEC economies, the only significant investor in wind power is the US. Other OECD members within APEC such as Japan, Australia and New Zealand have a small amount of installed wind power capacity, but annual installation growth rates are much below those of the industry leaders.

SOLAR

Substantial reductions in capital cost will be necessary for solar power technologies to compete with lower-cost options. In the Asia-Pacific, solar will find niche applications for remote area power supplies, and in situations where governments seek to actively encourage greater utilisation of this technology through various promotional schemes.

Most future growth will be in photovoltaics (PV) for building applications and remote power systems, although there are also good prospects for passive solar thermal power for heat production.

Table 12 Installed PV power in selected APEC economies in 1999 (MW)

	Total Capacity	Off-Grid	On-Grid Distributed	On-Grid Centralised
Japan	205	57	146	3
US	117	84	21	12
Australia	25	23	1	1
Mexico	13	13	0	0
TOTAL	**360**	**177**	**168**	**16**

Source: IEA (2001c).

Nearly half the total PV capacity installed in the APEC region is used in off-grid applications. Most on-grid applications are found in Japan, and are mostly distributed (in buildings). Japan has the highest PV capacity of any country in the world as a direct result of the 'Residential PV System Dissemination Programme' initiated in 1977. This provides investment subsidies to individuals, real estate developers and local organisations involved in public housing projects. In 2000, government support was US$2,505/kW up to 10 kW and US$1,670/kW up to 4 kW. PV systems were installed in nearly 19,000 homes in 2000. Since 1994, a total of 51,899 houses have installed PV systems.

CHAPTER 4

ALTERNATIVE ELECTRICITY DEVELOPMENT SCENARIO

INTRODUCTION

The purpose of this alternative electricity scenario to 2020 is to consider the effect emerging technologies and measures could have on electricity demand and supply in APEC over the forecast period. If a greater emphasis were placed on more efficient electricity consumption and generating electricity in a more environmentally friendly manner, then it is anticipated that significant reductions of fuel use and carbon emissions could be realised across the 21 APEC economies. This analysis will develop a plausible scenario that is based on technologies that are, or will most likely become, economically market viable over the forecast period. However, it is anticipated that to achieve such results it would require significant government policy formulation and implementation to overcome significant market barriers.

Furthermore, this scenario is based on a set of reasonable but fairly aggressive assumptions. These assumptions have a wide range of possibilities, and their applicability and impact on derived results for any economy could vary significantly. The main objective of doing such a scenario is to demonstrate what possible impact such assumptions could have on the APEC region. Additionally, it is suggested that each APEC economy consider policies to achieve reductions in energy demand and more environmentally friendly supply without negatively impacting GDP growth.

This scenario is based on the following key areas of focus:

- Greater share of less carbon intensive fuels, including natural gas and nuclear at the expense of coal and oil.
- Greater share of new and renewable energy including biomass, small hydropower, wind, and solar.
- More efficient centralised electricity generation technologies, including greater rates of refurbishment and retirement of older generating plants.
- Retrofit and increased penetration of cogeneration through distributed generation for new industrial and commercial facilities.
- Retrofit and increased penetration of more efficient demand side technologies in the residential, commercial, and industrial sectors.

This chapter is divided into three main sections. The first provides a general background of the technologies. The second discusses the analytical framework and assumptions. The third presents the results of the scenario compared with the reference case for APEC as a whole and for Economy Groups A, B, and C.[51] The results presented include electricity demand, fuel inputs and shares, and carbon emissions.

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51 APERC (2002a).

BACKGROUND – TECHNOLOGIES AND MEASURES

CENTRAL POWER GENERATION

Centralised power generation facilities refer to large systems that are always connected to the grid. The focus here is on natural gas- and coal-fired systems, although there are other types of power plants such as nuclear, geothermal and others, but they will not be addressed with regard to new technologies.

GAS TURBINE TECHNOLOGY

COMBINED CYCLE GAS TURBINE (CCGT)

In this process high-pressure air is generated by a compressor and enters the combustion system together with fuel, and combustion takes place. The resulting hot gases expand through the turbine, which drives an associated electrical generator and air compressor. Exhaust gases from the turbine are directed to a heat recovery steam generator (HRSG) before being discharged to the atmosphere. Steam produced in the HRSG expands through the steam turbine, which drives an electricity generator. The steam leaving the turbine is then condensed and recycled to the HRSG.

Currently this technology achieves thermal efficiencies of around 45-55 percent on a lower heating value basis (LHV), higher in co-generation configurations. A number of programmes in the US and other APEC economies are working towards the development of advanced technologies that will enhance the efficiency and environmental performance of turbines. The objective of these programmes is to achieve thermal efficiencies approaching 60 percent or more in a combined-cycle mode and a reduction in emissions of NO_x. In the past the road to higher efficiencies was blocked by a heat barrier, and temperatures above 2,300 degrees Fahrenheit (1,260 °C) caused metals in the turbine blades and in other internal components to begin degrading. However, recent developments in the use of advanced materials and revolutionary new steam-cooling technology have increased the temperature at which turbines can operate to 2,600 degrees Fahrenheit (1,427 °C).[52]

CLEAN COAL TECHNOLOGY

As concerns over the impact of fossil fuel extraction and combustion increase, a growing number of governments and companies have increased research into so-called 'clean coal technologies'. For example, the US administration in its *National Energy Policy Report* of May 2001 recommended that US$2 billion over 10 years be provided for research into clean coal technologies.

Clean coal technologies are a family of technological innovations that are environmentally superior to the technologies in common use today. They consist of new combustion processes – like fluidised bed combustion and low NO_x burners – that remove pollutants, or prevent them from forming, while the coal burns. They can be new pollution control technologies that clean pollutants from flue gases before they exit a smokestack. They also include new processes that convert coal into other energy forms that can be cleaned before being combusted, for example, converting coal into a gas that has the same environmental characteristics as clean-burning natural gas.[53]

The coal technologies that have been incorporated into electricity generation sector for the alternative scenario, are predominately supercritical steam cycles, fluidised bed combustion and integrated coal gasification combined cycle.

52 United States Department of Energy – Office of Fossil Energy (US DOE - FE) (2001a).

53 United States Department of Energy – Office of Fossil Energy (US DOE - FE) (2001b).

SUPERCRITICAL STEAM CYCLES

Sub-critical steam cycles represent the current dominant coal technology for electricity generation; the process of converting heat from fuel into electricity is operated well below the steam/water critical pressure of 221.2 bars. By increasing the operating temperature and pressure, greater thermal and environmental efficiency can be obtained.

Current supercritical power plants can achieve efficiencies of around 45 percent (LHV), however, steam temperatures and efficiency have gradually increased, and state-of-the-art plants are expected to operate at 620 °C within the next few years, and by 2020 may have achieved temperatures of 650-700 °C and efficiencies in the range of 50-55 percent (LHV).[54]

FLUIDISED BED COMBUSTORS

Fluidised bed combustors remove pollutants inside the boiler – no scrubber or post combustion sulphur and nitrogen controls are needed. Rather than burning coal as a blown-in powder, fluidised beds mix pulverised coal with limestone and suspend the mixture on jets of air in a floating 'bed'. The limestone removes sulphur as it is released from the burning coal and converts it to an environmentally benign powder. The turbulent action also reduces the temperature of the combustion process below the threshold where large amounts of NO_x form.

This technology can combust a wide range of variable quality fuels and wastes. The fluidised bed can be fuelled with low-quality coals, washing wastes, sewerage sludge, municipal waste and tyres.

Pressurised fluidised bed technology operates at increased pressures and enables sufficient generation of flue gas energy to drive a gas turbine, which is recovered before being exhausted to the atmosphere. Electricity is therefore generated from both the gas turbine and the conventional steam turbine, raising the thermal efficiency by around 10 percent above conventional coal-fired technology, which does not utilise a gas turbine.

INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)

This process turns coal into gas, which can be cleaned of its impurities to levels similar to natural gas. The gas is then combusted in a gas turbine to generate one source of electricity. Exhaust from the gas turbine is used to produce steam to drive a steam turbine and generate a second source of electricity. This 'combined' effect can boost thermal efficiency by as much as 20 percent above conventional coal-burning power plants today and could eventually double today's efficiencies.[55]

COAL QUALITY

The efficiency of many coal plants in the Asian region is well below that for developed countries. This is due to the age of the plants, relatively small unit sizes in comparison to OECD countries, old technology, poor maintenance and inferior coal quality. For example, the average thermal efficiency of coal-fired stations in China is around 32 percent (LHV). This compares with an average of around 36 percent in economies such as Australia and the US and around 40 percent for new power stations using pulverised coal technology, 45 percent if supercritical steam technology is used.

One of the major reasons that thermal efficiency in many non-OECD countries is so low is the poor quality of the coal. In China, for example, many power stations experience problems with poor quality coal of inconsistent characteristics. Cleaning of coal can result in a more consistent

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54 DTI UK (1999).

55 US DOE.

quality with lower ash levels. This clean coal can also increase the thermal efficiency of existing power plants by at least 2-3 percent and potentially up to 4-5 percent.[56]

EXISTING PLANT REFURBISHMENT

An option that may be attractive to some APEC economies, in particular China, is the refurbishment of existing power plants. Due to the large number of 'old' power plants in some economies where investment funds may be limited, a cheaper alternative is to improve the efficiency and reliability of existing plants. These improvements can be instituted in a number of different areas, including replacement or optimising turbines and/or pulverisers, improving firing techniques, and the adoption of control optimisation systems that are designed to minimise the coal consumption of coal-fired power stations through automatic control. Such measures have shown that the thermal efficiency of existing power stations could be increased by 3-4 percent.[57]

DISTRIBUTED POWER SYSTEMS

Distributed technologies usually represent a group of modular, smaller-scale technologies capable of being operated at or near the intended load. They would normally comprise power systems driven by natural gas or diesel reciprocating engines. However, advances in renewable energy technologies make applications for mini or micro-hydropower, wind turbines, photovoltaics (PV) and fuel cells viable in many situations. Also, advances in gas technologies make micro and mini-turbines and in the near term fuel cells attractive for certain applications. Large gas turbines including combined cycle systems can be used for large industrial or commercial complexes.

The following is a brief summary of these technologies. A full discussion was presented in an earlier APERC report − please see Chapter 3, Emerging Technologies, of *Sustainable Electricity Supply Options for the APEC Region*.[58] Also, the remaining discussion for this section takes account of earlier APERC work. The cogeneration section, for example, is rather lengthy because APERC has not previously presented this material, while it has previously presented in-depth studies on demand reductions and policies. Thus only limited summary data is presented here.

SMALL-SCALE HYDRO

Small-scale hydropower resources generally include either run-of-the-river or low head power generation, and generally encompass resources that are less than one MW in size.[59] Because these systems are small, many opportunities exist for the application of this type of technology. Small-scale hydropower schemes avoid most of the undesirable impacts of large-scale developments, and can produce electricity where it is needed (avoiding transmission losses). For example, small-scale hydro schemes could provide power to remote and poorer communities in developing economies where the resource is available (for example China, Indonesia and the Philippines).

WIND

Electricity generated by wind turbines is emission free. Wind can play an important role in peak demand mitigation in certain circumstances, and can also contribute to rural and village power needs. Costs have decreased significantly over recent years and in places with high-quality wind resources, wind turbines are now competitive with other technologies.

SOLAR PV

PV cells are solid-state semiconductor devices with no moving parts that convert sunlight into direct current electricity. Electricity generated from PV systems has no emissions. Small and

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56 Couch (2000).

57 NEDO.

58 APERC (2001b).

59 WEC (1994).

stand-alone PV systems are ideally suited to many areas within APEC where connections to the grid are too costly or impractical.

GAS MICRO TURBINES

Small-scale versions range in capacity from around 25 kW to 1 MW. Generation thermal efficiencies are of around 25-30 percent (LHV), but waste heat can be used for space heating, water heating, or even cooling with the appropriate equipment such as indirect absorption chillers. System efficiencies can approach 70 to 80 percent. They are reliable and have very low emissions.[60]

FUEL CELLS

A fuel cell uses a chemical reaction to convert fuel (hydrogen) directly into electricity with very low or almost no emissions. Modern fuel cells intended for transport or building/industrial use rely on a variety of fuels such as gasoline or natural gas, but also can use methane and biogas. This requires the use of an initial reformer process to convert the hydrocarbon fuel into hydrogen, which is then passed through the fuel cell to produce electricity. The by-products of the process are water, heat and electricity if pure hydrogen is used. Even when typical fuels are used the emissions are low, and they operate very quietly. When the waste heat is recovered such as for space heating or other applications, efficiencies can reach 80 to 90 percent.

APPLICATIONS

'Distributed' does not necessarily mean that the load or the technology is not connected to the grid. Rather, it means that any power produced by the modular technology would largely displace transmitted power. This system differs from the historic idea of diesel-powered back-up generators, because in a distributed power system the individual generation units provide either base-load or peaking load on a regular basis, and the small-scale producer may even sell power back into a distribution network.

The underlying concept of distributed power may not be particularly new – early power systems were of this type – involving the generation of electricity close to centres of demand, usually in small-scale generation plants. This avoids transmission and distribution losses, and facilitates recovery of waste heat for space and water heating, or even cooling through advanced systems.

In systems where transmission capacity has become a constraint (true in many developed economies), this trend avoids the need for costly grid upgrading. In developing economies, a 'green field' design can take advantage of the latest technological advances in the entire energy delivery system. An example would be to provide a gas pipeline to a large commercial, industrial or institutional complex, then to generate the required electricity rather than to use transmitted power.

A distributed power system would ideally include a variety of energy resources, all of which are likely to be significantly more environmentally friendly than the mix of large-scale generation technologies. Newly emerging distributed power technologies should also find applications in poorer, developing economies that still require large-scale base-load capacity growth, primarily in more remote areas, or in growing industrial or commercial zones where both electricity and waste heat can be utilised. The use of these systems in lieu of, or to supplement, grid power offers a variety of benefits.

The possibility of renewable energy applications growing at extraordinary rates was discussed earlier. Distributed power systems and what they have to offer will be one of the reasons why renewable energy technologies will achieve very high growth rates. Renewable energy technologies will have a direct impact on reducing the requirements for capacity expansion of central power systems.

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60 Valenti (2000).

PEAK DEMAND MITIGATION

An obvious role for small-scale distributed power systems is to supplement grid power, and manage the load for individual consumers. For example, although commercial and industrial electricity consumers can negotiate term supply contracts in some deregulated power markets, this is not universally possible, and many consumers face high electricity rates at times of peak power demand. Also, many industries and vital service providers (for example hospitals) require un-interruptible supply. As seen in California in the winter of 2000-01, this cannot be guaranteed even in wealthy, highly developed societies, and costs of power disruption can be so high that the cost of investment in distributed power systems is easily outweighed by the risk of loss of supply.

Currently, there are many applications of distributed power technologies that are justified on the basis of risk rather than direct competition with central generation from the grid. These applications include emergency power, remote power and experimental applications. However, there are many distributed power applications that recover waste heat almost 100 percent of the time that can compete on a cost basis with grid power.

COGENERATION

The term 'cogeneration' is not new and has been used in large-scale facilities in APEC economies for many years. However, smaller-scale technologies such as gas mini and micro-turbines, and eventually fuel cells have made cogeneration technically feasible and cost-effective for an entirely new array of applications. In many economies, the new term associated with cogeneration applications is combined heat and power (CHP). APERC has chosen to maintain the conventional term 'cogeneration'.

Typical efficiencies of central power generation range from around 30 percent for coal- and petroleum-fired plants to around 55 percent for combined cycle gas turbine plants. The efficiency when it reaches the end-user is further reduced by system losses, bringing the typical efficiency to around 25 to 50 percent.

Similarly, distributed technologies such as gas or diesel engines generate electricity on site with efficiencies ranging from about 30 to 50 percent. Micro turbines generate electricity with about 25 to 30 percent efficiency. Thus, without cogeneration applications, the efficiencies of distributed technologies (with fossil fuels) do not offer significant efficiency savings. However, there are experimental 'hybrid systems' using fuel cells and micro turbines together that will generate electricity on-site with an efficiency of about 80 percent. When these types of systems become mainstream and affordable, even greater opportunities for distributed power will exist because these high efficiencies will be achieved without requirements for properly utilising waste heat.

When waste heat is utilised with the current commercially available technologies, system efficiencies for fossil fuel distributed applications reach the 80 percent range and higher. These offer enormous savings over centrally generated electricity and on-site electricity generation that does not make use of the waste heat. The most common and easily comprehensible applications for waste heat include simple industrial process heating such as preheating water, products or fuels, or space heating for commercial buildings. However, the use of waste heat for cooling applications is hard for many people to understand. Yet this virtually untapped application can offer significant opportunities in developed and developing economies for commercial buildings with significant cooling loads.

Figure 20 shows applications in Malaysia, where large-scale distributed generation technologies are used to generate electricity and the waste heat is used for cooling. The total installed electricity capacity of the three projects (Kuala Lumpur International Airport, Petronas Towers, and Putrajaya Federal Government's Administrative Building) is 73.8 MW and the cooling capacity is 82.5 RT (refrigeration tonnes).

Figure 20 Distributed generation applications in Malaysia

Note: Kuala Lumpur International Airport, Petronas Towers, and Putrajaya Federal Government's Administrative Building (clockwise).

Source: *GDC and Cogeneration System, For Healthier Living, Gas District Cooling Brochure*, Petronas Company.

Figure 21 shows a schematic of the technical systems and the various components used to generate electricity on-site and to provide cooling to the associated buildings.

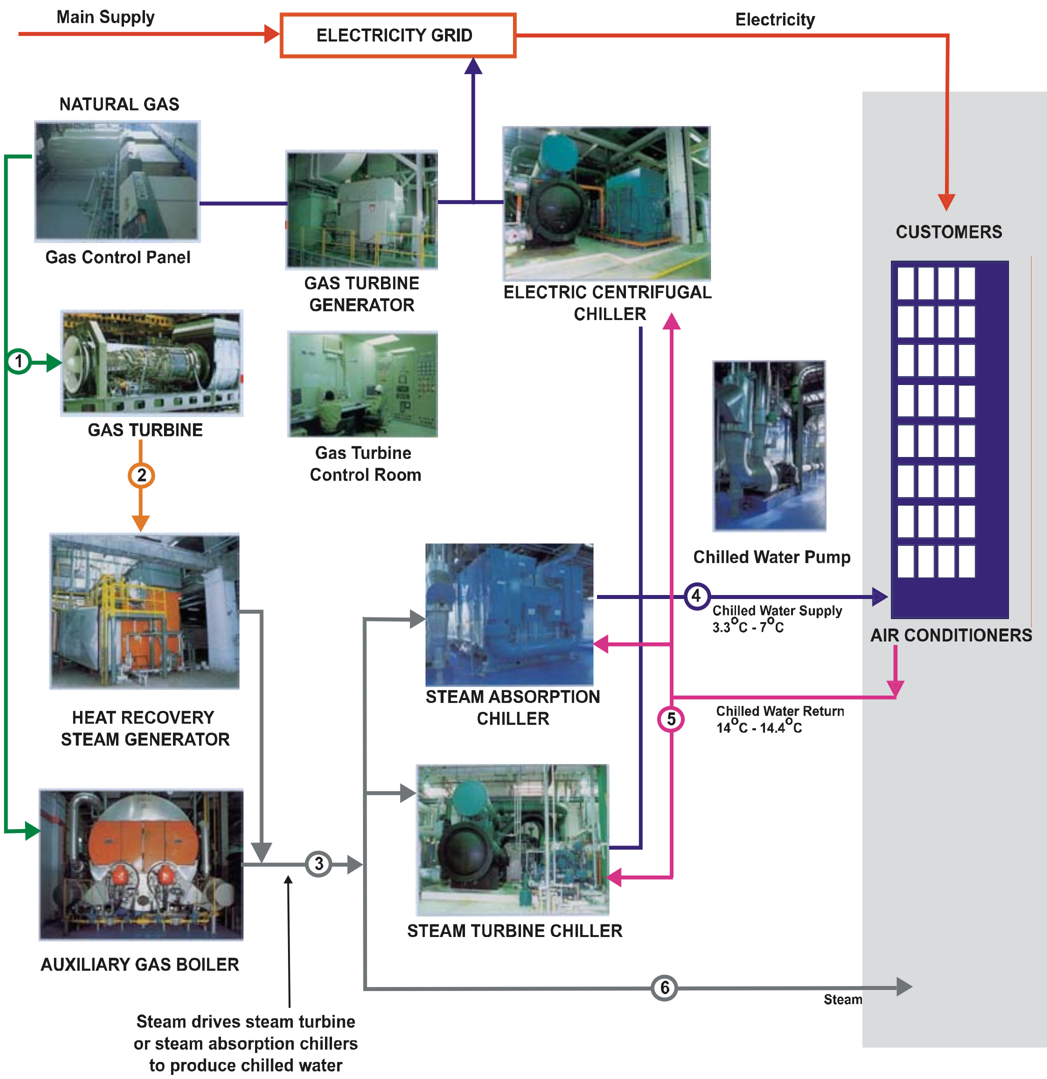
CONSIDERATION FOR COST EFFECTIVE APPLICATIONS

The significant technical energy and environmental savings potential for distributed power applications with full use of waste heat are illustrated above. However, the obvious concern that needs to be addressed is the economics for the implementation of such technologies. There is a wide array of issues that affect the economic viability of cogeneration applications. Many may be too technical for the scope of this study, but the main concerns and considerations will be discussed.

First of all, successful and cost-effective cogeneration projects involve the full assessment of local conditions and the application of appropriate technologies for the specific project. There are many generic guidelines, but almost all applications require individual assessments from a technical and economic perspective.

One of the most critical issues is the proper 'matching' or suitability of waste heat recovery to electricity generation requirements. Not all activities are suitable for cogeneration, but smaller technologies such as micro turbines or fuel cells will allow for the installation of systems that are most economic. Not all of the electricity generation or heat load needs to be handled by the distributed technologies. Issues such as large fluctuations in either waste heat use or electricity demand because of industrial production requirements or seasonal concerns can have major impacts. These issues can be addressed by the appropriate design and sizing of the system.

Figure 21 Typical Malaysian cogeneration systems providing cooling



Source: *GDC and Cogeneration System, For Healthier Living, Gas District Cooling Brochure*, Petronas Company.

Whether the system will be independent of the grid and will be required to provide all of the electricity rather than to use grid power in particular situations will also be a very important design criteria. In a scenario without a grid connection, some excess electricity capacity will be required that will have a negative financial impact. At the same time, if the grid interconnection costs are not required then there will be financial advantages.

The complexity of the system is also a major concern. For example, if waste heat is used to preheat industrial process water, then the nature of the system is rather simple. Additionally, this type of system would have lesser components and would require less maintenance. If an application had process water requirements that were directly linked to the electricity demand for the industrial process, then the design considerations would be relatively simple. Systems of this nature represent the majority of existing cogeneration applications. The introduction of smaller-scale distributed power technologies such as those discussed above has expanded this relatively simple design scheme to a host of new applications.

More complex systems offer an even greater number of possible installations. Although these systems may require more assessment, engineering, planning and maintenance, they may offer even greater net energy and environmental savings. Many plant designers or energy managers are not fully aware of the host of possible applications, therefore the implementation of such systems is never considered.

The cost of the competing system (or grid power) is also a major consideration. Most industrial electricity pricing schemes include 'demand' and 'consumption' components. Thresholds or limits of demand (maximum power draw) are often imposed with contract sales or based on historical trends. Sometimes when these limits are violated the end-user may have to pay enormous premiums. Thus, historical violation of preset demand limits needs to be considered in the economic assessment. Also, the possibility and revenue potential for selling electricity back to the grid needs to be considered. The entire cost and revenue opportunities of grid power are a major consideration for the cost-effective applications of cogeneration systems.

The cost of electricity varies significantly among the APEC economies, as do regulatory concerns for selling power to the grid, environmental regulations and permitting, seasonal issues, access to affordable natural gas, domestic coal, renewable resources and other issues. All of these issues combined make the cost-effective application of cogeneration technologies even more challenging to determine. However, from the fundamental nature of many industrial processes using enormous amounts of heat, and commercial buildings with large heating loads in colder climates and large cooling loads in hotter climates, there is a very large potential for energy and environmental savings that is not being realised.

With greater exposure of the possible applications, such as the Malaysian examples mentioned above, each economy's goal should be to get its industries and commercial building designers to consider such measures. Proper analysis should include life cycle cost assessments so that the overall least-cost options and greatest energy saving potentials are realised.

CURRENT COGENERATION PENETRATION IN APEC

Acquiring detailed cogeneration data to determine existing penetration rates in APEC can be difficult. Many entities are private and may not have the same reporting requirements as large central power facilities. Often, large cogeneration facilities are connected to the grid, so the data may be available. APERC collected and analysed available data including electricity generated by cogeneration facilities and/or installed capacity of cogeneration facilities. Generation data is preferable since it directly relates to the actual use of the facilities rather than the possible use, but consistent data for the majority of the APEC economies was lacking. Even for some of the most developed economies, the quality and reliability of the data were not as good as desired. There were, however, a few key findings.

For example, Russia has the highest cogeneration within APEC, with a large number of 'distributed heated' commercial buildings using waste heat generated from power generation. This represents about 30 to 50 percent of the installed electricity capacity. Other than Russia, cogeneration in the commercial building sector is very low in almost all APEC economies. Industrial penetration generally ranges from around 10 to 20 percent penetration of installed electricity capacity for some of the more developed economies, to about 0 to 5 percent for most of the developing economies.

COGENERATION POTENTIAL IN APEC

Several studies have been conducted to estimate the potential cost-effectiveness of cogeneration installations in some APEC economies. Usually the approach is to estimate technical potential based on the industrial sub-sector prevalent in a particular economy, and sometimes the commercial and/or institutional sectors are also assessed. Then, the potential is reduced based on 'real world' or economic considerations. The usual net result is an estimate of a particular value, or installed capacity, of cost effective cogeneration potential, for example 1,000 MW.

This approach is very reasonable for a 'rough order of magnitude' of cogeneration potential. From the discussion above, though, it is obvious that each individual project will need to be assessed based on the macro issues of the economy (meaning fuel costs, electricity grid costs, regulatory requirements and others) and on the micro issues of the individual application (type of business, daily demands, seasonal demands, cost of financing and many others).

Many of these studies are static and only look at the existing potential. This is reasonable for policy-makers to determine if various programmes should be implemented to promote cogeneration applications. However, the forecast for electricity growth over the next 20 years, driven by massive increases in GDP and thus industrial, commercial and institutional activity, will present an enormous number of new opportunities for cogeneration applications. If we combine conventional applications that have not been fully utilised with a new set of applications that are possible because of the new technologies presented above, and then add in the array of new applications because of increased activity, the combined potential is probably much greater than anyone has predicted.

Even though this large potential exists, it still will be difficult to realise modest amounts of the cogeneration potential. With an array of policy programmes to encourage the installation of cogeneration projects, market barriers will still be formidable. Market barriers exist at the macro or economy level on issues such as regulatory reform for the sale of electricity or of environmental permits. Barriers exist at the micro level, such as the basic lack of information for the project decision makers. However, APERC believes that under an alternative scenario with the appropriate cost-effective policy measures, a significant potential for energy and environmental savings could be obtained through the improved implementation of cogeneration applications.

ELECTRICITY DEMAND REDUCTION

The reference forecast shows strong electricity demand growth. Inherent in these forecasts are modest improvements in energy efficiency and structural changes. Thus, end-use sectors for most economies are becoming less energy-intensive and more efficient over time relative to GDP growth. However, much more aggressive improvements in energy efficiency can be achieved that are cost-effective.

The alternative scenario assumes significant improvement in energy efficiency that could occur as a result of various policy and programme mechanisms. The goal is to reduce electricity demand in the three main end-use sectors − industrial, residential and commercial buildings. In all economies, the result will be reduced growth in electricity demand rather than an actual reduction in demand. Population and GDP growth will result in significant increases in output. Additionally, as consumers become wealthier they desire more amenities such as larger homes with additional electrical appliances and equipment.

APERC has conducted several projects involving energy efficiency. In Chapter 8, Energy Efficiency Policies, of the APERC report *Energy Efficiency Indicators*,[61] a range of policies for all APEC economies was analysed. Furthermore, macro issues such as market barriers, government intervention, technology development and cost-effective analysis were discussed in detail. A full range of policies including all sectors (residential, commercial, industrial and transport) was discussed including voluntary and mandatory mechanisms. Generally, if economic assessments are done on a private or public basis using a net present value or life cycle cost analysis, then these activities can be pursued with no additional financial or economic burden. Installation of cost-effective energy efficiency measures requires substantial investment and financing, but the recurring energy and financial savings exceed the payment requirements for the financing. Thus, the net effect has either zero or positive cash flow implications.

This alternative scenario assumes that many opportunities for cost-effective energy efficiency measures are realised. The following examples are provided to illustrate several areas that have significant opportunities. During the new construction of a facility or building many unique opportunities exist, but the designer or developer may not even be aware of such considerations. Commercial buildings can be designed with proper orientation, natural shading and reflective

61 APERC (2001a).

windows to reduce solar gain, thus resulting in lower cooling loads. Integrated natural lighting and automated dimming electronic ballasts can be installed to significantly reduce the lighting loads. Space conditioning ducts can be properly sealed to reduce fan speed, thus reducing the fan power requirement by a cubed function. Space conditioning equipment can become very efficient and affordable when purchased on a competitive basis. Many of these types of improvements get installed on a limited basis in even some of the least-developed economies. However, mainstream deployment of energy-efficiency packages during new construction is vastly under-utilised in all APEC economies.

If we look at the residential sector, similar opportunities exist. For example, the thermal shell of a building can be drastically improved by using thicker walls, superior windows and better insulation techniques for foundations and slabs. Interior electricity consuming equipment also offers significant opportunities for improvements, ranging from efficient appliances and lighting to electronic devices and chargers. Many homes have historically used fossil fuels for heating, but there will be a significant number of homes built in APEC that will use electric heat pumps for heating and electric air conditioning for cooling. The US 'Building America' programme that promotes the construction of energy-efficient homes has demonstrated the ability to reduce the energy consumption of new homes by over 40 percent without any additional cost. Yet these homes still represent only a fraction of new home sales due to a variety of reasons that can be mostly attributed to 'market barriers'.

The industrial sector offers significant opportunities for electricity reduction. The high energy-intensive industrial sector, such as the cement industry, has very high consumption of fossil fuels, but the electricity consumption can still be significant. Generally, the low energy-intensive industrial sector, such as fabrication or mechanical assembly, has significant consumption of electricity, which may be the predominant fuel.

Any industrial facility may have opportunities similar to commercial buildings if there is lighting or space conditioning. For example, sulphur lamps have been used in light industrial facilities that have resulted in energy savings in the 50 percent reduction range.[62]

Electric motors account for a significant proportion of electricity consumption. For example, motors are often running 24 hours a day, seven days a week. The annual operating cost can far outweigh the procurement cost. Thus, improving their efficiency by just a few percentage points can have a noticeable impact. Often, motors are refurbished rather than replaced. This practice needs to be carefully considered. Sometimes the cost of a new highly efficient motor can be recovered in a relatively short time period.

Many industrial plants use compressed air for a host of applications. This air is generated with a compressor and electric motor. The US DOE has a Compressed Air Challenge Program to address issues regarding the generation, storage, distribution and use of compressed air.[63]

ANALYTICAL FRAMEWORK AND ASSUMPTIONS

The reference case is the starting point for the alternative scenario analysis. The reference case inherently has a certain amount of normal technological and energy efficiency improvements. Most of the demand-side improvements are not transparent. These were established using an econometric approach that takes into account major economic drivers such as GDP and population, while considering historical trends that include energy efficiency. For more information on this, please see APERC (2002a). Thus, the assumptions presented here are above

62 US DOE, http://www.eere.energy.gov.

63 Ibid.

this base level, which is expected to be rather modest, but it cannot be defined because of the econometric approach that also includes structural sectoral changes.

Supply efficiency and fuel choice assumptions are input into the LEAP model together with the fundamental assumptions for the reference case and the alternative scenario. Thus, the supply side is much more transparent.

The alternative scenario assumes that policy changes would take place so that implementation would begin in 2004 and continue until 2020. This is considered the Policy Period. However, many policies do not take effect until after 2004, and the assumptions have been made bearing in mind the plausibility of them taking effect in 2004. It is noted, though, that for such a scenario to occur, significant changes to current public policy would have to be in place soon.

Supply and demand are the two primary elements of the alternative scenario. Therefore, the analytical model was calculated for these two areas independently. Thus, there will be an Alternative Supply and DSM-Cogen output for the scenario. The supply outcome includes increased low-carbon fuels, greater renewable energy, and improved generation efficiency. The DSM-Cogen results include traditional demand-side reductions and equivalent cogeneration savings. Since cogeneration will save energy at the site by displacing fuels that would have been used for purposes other than electricity generation, it is difficult to show the results. Therefore, to simplify the results, a conservative analytical method was used to establish equivalent fuel savings for the grid, or central generation. Thus, the impact from cogeneration was included with demand reductions and is shown combined as the DSM-Cogen Alternative. It is noted that cogeneration will actually decrease grid fuel consumption and increase on-site fuel consumption, and only the net savings (using a conservative method) were included for grid fuel use consumption and carbon emissions.

The third output combines these two sets of measures. However, it must be noted that when both areas are combined significant diminishing returns will occur. For example, if there are reductions in demand, then the addition of more environmentally friendly and efficient supply may not be needed. Conversely, if there is very efficient central generation supply, then a cogeneration policy programme may not make sense.

In the market place, the choice between increased demand-side measures and improved supply will be handled by the various entities involved taking into account the current government policies. In most cases, decisions on demand reduction and improved supply are made by different people and are really not a concern. However, they are a concern for those involved in public policy. Thus, the LEAP model does not duplicate savings by simply combining the two sides of the equation. Each economy needs to consider its circumstances and establish the appropriate array of policies. For example, if one economy were adding generation with mostly low or non-carbon energy inputs, such as hydro, nuclear and wind, then an aggressive government policy to promote cogeneration would not be warranted. At the same time, if a facility operator in that economy sees an economic advantage in installing cogeneration without any severe negative environmental impacts, then that would be a prudent independent business decision.

GREATER SHARE OF LESS CARBON INTENSIVE FUELS

In this section, a greater emphasis is placed on the choice of natural gas and nuclear at the expense of more carbon-intensive fuels such as coal and oil. More details regarding the assumptions for each economy can be found in Annex I. However, the approximate macro fuel choice changes for the alternative scenario are presented in Table 13.

Table 13 Macro fuel choice assumptions for the APEC region

	Percent Change by 2010	Percent Change by 2020
Natural Gas	+ 9.4 percent	+ 6.7 percent
Nuclear	+ 0.3 percent	+ 8.0 percent
Coal	- 10.5 percent	- 17.7 percent
Oil	- 9.8 percent	- 4.9 percent

GREATER SHARE OF NEW AND RENEWABLE ENERGY

In this section, a greater growth rate is assumed for renewable energy. Biomass for coal co-firing in particular is expected to grow at significant rates, along with increases in geothermal, mostly from increased capacity at existing sites. In the second decade, wind and solar grow at higher rates but their total contribution is still fairly small. Hydropower is also expected to grow at higher rates in the second decade, with some large-scale hydro coming on line along with many small-scale systems. More details regarding the assumptions for each economy can be found in Annex I. However, the approximate macro changes for the alternative scenario are presented in Table 14.

Table 14 Macro renewable energy assumptions for the APEC region

	Percent Change by 2010	Percent Change by 2020
Biomass	+ 62.5 percent	+ 69.5 percent
Hydro	+ 0.1 percent	+ 0.9 percent
Geothermal	+ 16.8 percent	+ 30.0 percent
Wind and solar	+ 3.8 percent	+ 37.5 percent

CENTRAL GENERATION PLANT EFFICIENCY

The reference case shows improvement in the efficiency of power plants, whereas the alternative scenario shows greater improvements. Table 15 shows the assumptions used in both the reference case and alternative scenario. The alternative scenario is based on the research and development programme of the US DOE Office of Fossil Energy. Recently an advanced, state-of-the-art gas power plant achieved 60 percent efficiency. Thus, the assumption is that this technology will need to be widespread throughout APEC by around 2007 to allow for construction and commissioning by 2010. The goal of the coal R&D programme is to achieve 52 percent efficiency by 2008. However, APERC believes that this level would be too aggressive for fully successful development and dissemination throughout APEC by 2007, thus the level was lowered to 45 percent efficiency. The level for oil was assumed to be consistent with natural gas because of similarities with combined cycle steam cycles. However, oil is expected to make a minimal contribution to the future supply mix.[64]

[64] US DOE, http://www.fe.doe.gov.

Table 15 Central generation power plant efficiency assumptions

Scenario	Oil 2010	Coal 2010	Natural Gas 2004
Reference case	53.7 percent	37.6 percent	55.0 percent
Alternative scenario	60 percent	45 percent	60 percent

Sources: US DOE - FE (1999), Siemens (2002).

RETROFIT AND PENETRATION OF COGENERATION

To assess or predict a plausible amount of cogeneration penetration under an alternative scenario is fairly challenging, especially for the APEC region. Several issues can be considered. First, if most developed economies have much higher rates of cogeneration penetration compared with most developing economies, then one can assume that increasing the rate of penetration for developing economies to that of developed economies is possible with the correct policies. Thus, penetration can be achieved through technology transfer and the appropriate cogeneration programme promotion.

Second, for developed and developing economies to make strides in the implementation of cost-effective cogeneration potential, new policies, coordination and aggressive measures will need to be pursued. Macro issues such as environmental concerns, local air quality, and others discussed in this study may help formulate a desire among the APEC economies to pursue alternatives to conventional central power facilities such as coal-fired power plants. Cogeneration will be one of the viable options that each APEC economy should consider in its policy portfolio.

The US economy has initiated comprehensive programmes to significantly increase the penetration of cogeneration in the industrial and commercial building sectors. The United States Combined Heat and Power Association, in cooperation with the US Department of Energy and Environmental Protection Agency, developed a national plan called the National CHP Roadmap that has the goal of doubling CHP applications from 46 GW in 1998 to 92 GW in 2010.[65] This aggressive plan was the result of over two years of interaction among industrial and commercial customers, equipment manufacturers, research organisations, governments, utilities and many others. The key elements of the plan call for information dissemination, elimination of regulatory and institutional barriers, development of CHP markets, and technology R&D.

A study conducted by five US national laboratories also predicted future industrial cogeneration penetration as a method to mitigate carbon emissions. Basically, the study established moderate and advanced scenarios above a reference case that were based on varying levels of government policies and participation by the private sector. The moderate case predicted about a 31 percent increase by 2010 and 84 percent by 2020. The advanced case predicted about a 64 percent increase by 2010 and 168 percent by 2020.

If one considers the above estimates along with suggested government policies, it is easy to conclude that it will be very difficult to estimate a plausible potential for energy savings from cogeneration across 21 APEC economies, especially when the required policies suitable for each economy are unknown. There are two broad categories of possible cogeneration applications across both the industrial and building (including commercial and institutional) sectors. These are 'retrofits' representing the installation of cogeneration to existing buildings and facilities, and 'new installations' for new buildings and facilities. Distinguishing between new installations and greater use of existing facilities is difficult when we look at the required increases in electricity demand. However, as a general assumption and as a proxy, it is assumed that new demand can represent new

65 USCHPA (2001).

facilities or major facility/building refurbishment. The existing demand can be seen as a proxy for the possible electrical capacity for retrofit.

These two categories will require different policies and the rate of penetration will be quite different based on many factors. Furthermore, the extent or level of sophistication will most likely be quite different as well. Generally, new installations allow for greater opportunities to install more sophisticated systems achieving greater savings. At the same time, existing buildings and facilities occasionally go through major renovations that provide opportunities similar to new installations. But retrofits are usually more modest in scope. These issues are difficult to assess in a macro 21 APEC forecast. The goal is to establish reasonable assumptions for these two main areas of cogeneration installations.

First, the increased penetration for economies with relatively low existing penetration should be the most cost-effective and easiest cogeneration installations to obtain once market barriers are overcome. With regard to new installations, it can be assumed that within a reasonable time frame the penetration of cogeneration can be achieved relatively quickly.

For economies with a significant amount of cogeneration, approximately 10 percent or more, additional retrofit and penetration will be possible but these applications may be more economically challenging. Thus, the new technologies and applications discussed above will play a key role in achieving results. Therefore, the additional penetration of cogeneration in any economy, whether it has experience with cogeneration or not, will be fairly equally challenging, although these may be for different reasons. Economies with less experience will have significant market barriers and a lack of experience and economies with significant penetration will have less cost-effective opportunities without more involved systems (the easy installations having already been exploited).

Considering these issues, the range of penetration in APEC, and the new technological opportunities, the following macro assumptions are being used. It is expected that over the policy period of 2004 to 2020, additional cogeneration retrofit equal to 10 percent of the existing electrical capacity (in 2004, the start of the policy period) can occur above the reference case. This is equal to about 0.6 percent per year of cogeneration retrofit in the commercial and industrial sectors.

With regard to new installations, it is expected that by 2020 an additional 15 percent of new cogeneration installations above the reference case in the commercial and industrial sectors can occur. The penetration rate is assumed to increase annually, at a slow rate of growth. The first three years will have increases of 0.5 percent year, thus in 2006 the penetration will be 1.5 percent. Then, the remainder of the policy period will have one percent increases per year. Therefore, the penetration in 2010 will be 5.5 percent and in 2015 it will be 10.5 percent. The last year of the policy period requires only 0.5 percent to reach the goal of 15 percent in 2020.

It is noted that these are macro assumptions that may vary significantly from sector to sector, or economy to economy, but they are presented as a reasonable possibility rather than an unattainable scenario. To provide a perspective on how much cogeneration would occur under these assumptions, the capacity for the US was calculated. These assumptions for the US economy from 2004 to 2010 would result in about 15 GW of additional cogeneration capacity. This is lower than the CHP plan discussed above, which would expect about 23 GW over a six-year period, although 15 GW of new cogeneration installations would still be considered significant.

RETROFIT AND PENETRATION OF MORE EFFICIENT DEMAND SIDE TECHNOLOGIES

Estimating a reasonable and cost effective amount of electrical demand reductions from the reference case is rather challenging because many factors are not known and this study does not allow for the detailed analysis that is required. For example, many of the issues raised above in the discussion regarding cost effective applications for cogeneration are also applicable to demand reductions. Various studies have been conducted and many estimates for annual demand reductions have been presented. For example, in the Scenarios for a Clean Energy Future study,[66]

[66] US DOE (2000).

the results show about 1.4 percent per annum for electricity reduction from 2010 to 2020 in the residential sector for the moderate scenario. It also shows for the moderate scenario about 1.1 and 0.8 percent per annum for the commercial and industrial sectors, respectively. Furthermore, within the energy efficiency arena, often the nominal value of 1 percent reduction per annum is seen as a very challenging and desired level.

The concern with using a value of 1 percent that could be supported by the above data is that the reference case has inherent in it, some amount of energy efficiency improvements. These are considered to be modest, but still existent which will require some amount of policy formulation and programme promotion to be realised which is consistent with the historical trend. Therefore, to be reasonable but fairly aggressive a macro assumption of 0.75 percent per annum of additional demand reduction beyond the reference case will be the goal over the policy period. However, since new demand side reduction programmes take awhile to become established, the first three years of the policy period were reduced from 0.75 percent to 0.5 percent.

ANALYTICAL RESULTS

The results of the analysis will be presented in three main categories: demand, fuel consumption, and GHG emissions.[67] Within each category, results will be presented for Group A, Group B, and Group C economies, and for the entire 21-economy APEC region.

DEMAND

Looking at Figures 23 to 25, for Groups A, B and C, respectively, one sees that the demand reduction is not all that significant except for Group A. This is because in the less developed economies electricity demand is growing at very high rates, roughly five percent per year. Therefore, small reductions in demand do not have that much of an impact. These are economies that are adding large amounts of services, production and living amenities that have not previously existed. However, since the developed economies of Group A represent such a large proportion of the total electricity demand in APEC (shown in Figure 22), the demand reductions make a significant impact. Further analysis would suggest that demand reductions in Group A and Group B economies could be significantly more aggressive than the assumptions if the appropriate amount of investment funding were available.

[67] Emissions include carbon dioxide, methane and nitrous oxide, and are expressed as CO_2 equivalent.

Figure 22 APEC - Electricity demand projection

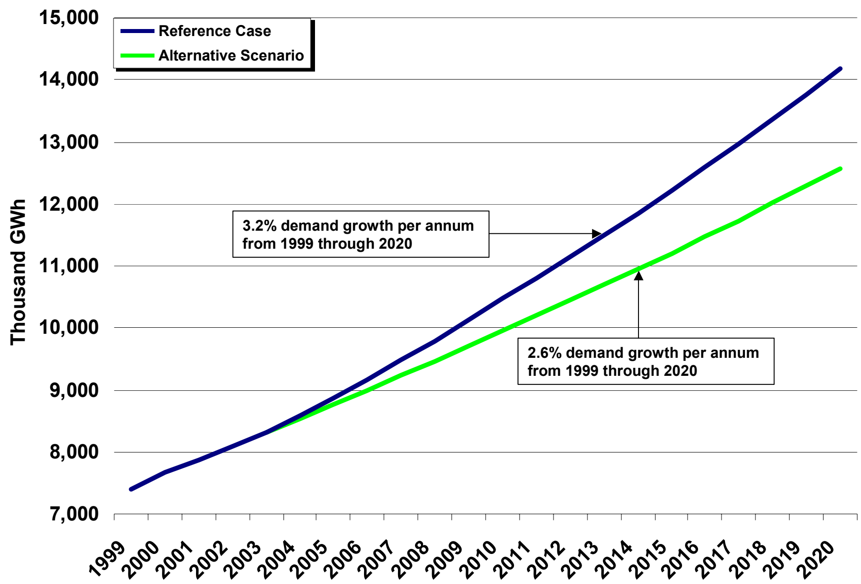


Figure 23 Group A - Electricity demand projection

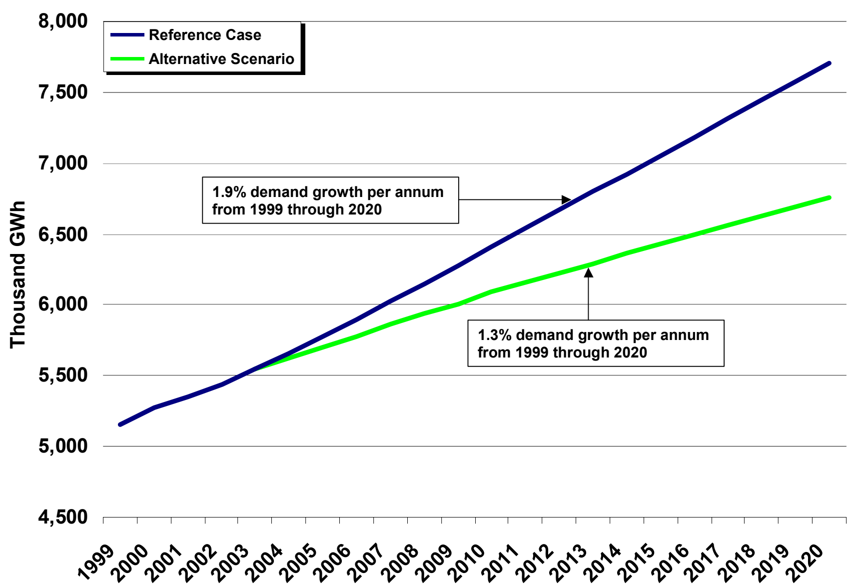


Figure 24 Group B - Electricity demand projection

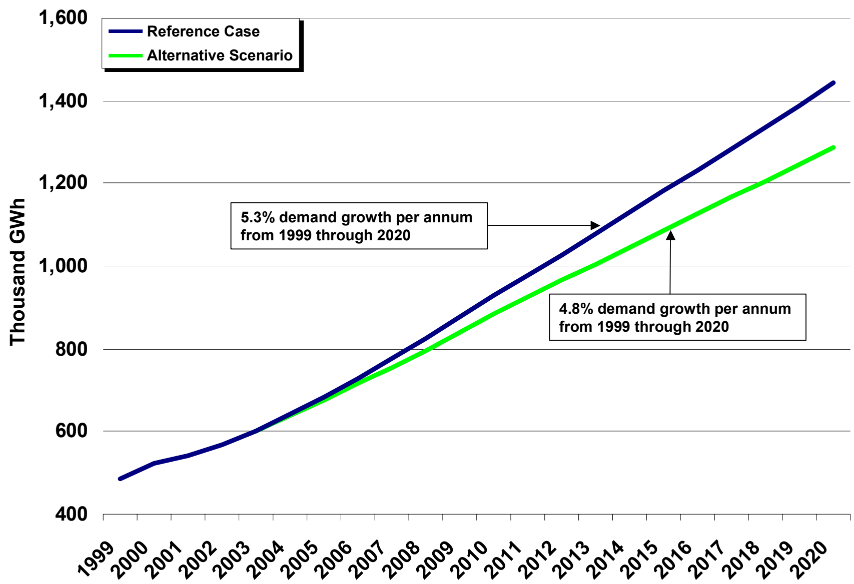
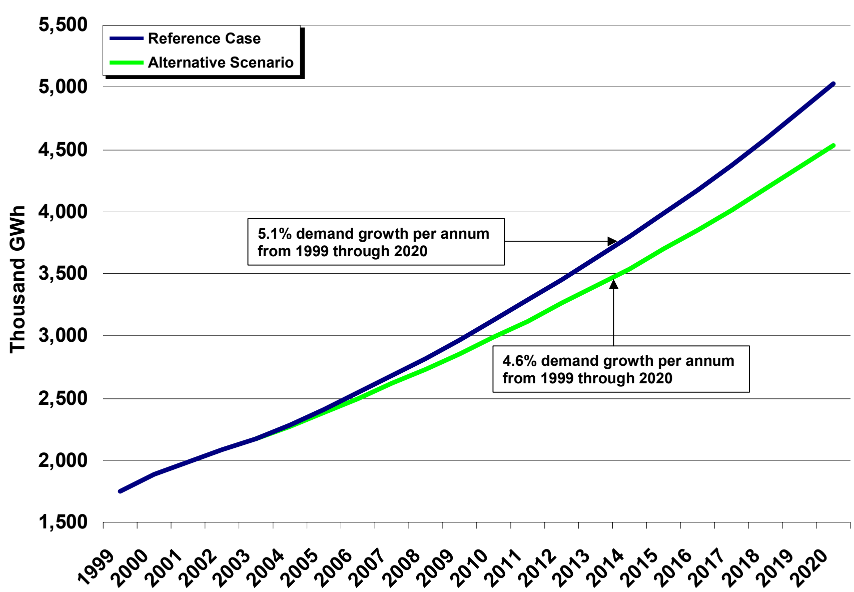


Figure 25 Group C - Electricity demand projection

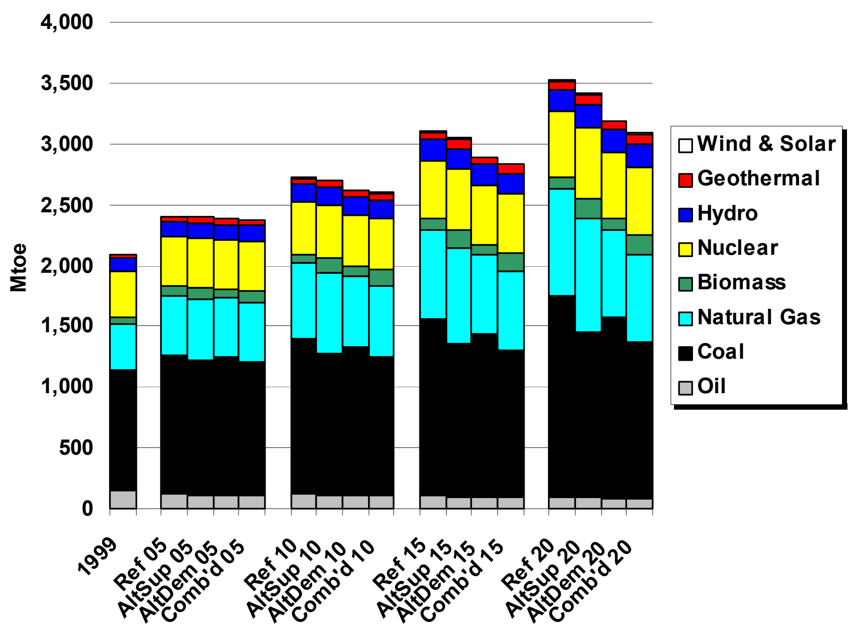


FUEL CONSUMPTION

As discussed earlier in this chapter, four different scenarios were simulated to come up with one single case that incorporates all the alternative assumptions in the demand and supply sides. These scenarios are the reference case (Ref in Figures 26 to 29), alternative supply case (AltSup), reduced demand case (AltDem) and combined alternative demand and supply case (Comb'd), which is a combination of the AltSup and AltDem cases. AltSup is where the assumptions on fuel switching and energy efficiency are analysed, while in AltDem the effect of reduced demand through DSM and cogeneration in supply projection is simulated. Comb'd incorporates AltSup and AltDem to come up with the combined effects of the alternative supply and reduced demand assumptions.

About 425 Mtoe of energy inputs for power generation could be saved if the assumptions in the alternative cases are realised in the future. This is equivalent to about half the 1999 energy inputs of the US or about double that of Japan in the same year. This also represents 12.1 percent of the fuel inputs in the reference case. Most of the savings will come from reduced consumption of coal of about 371 Mtoe, 147 Mtoe of natural gas and 17 Mtoe of oil. Some of these will be compensated for by higher consumption of biomass (65 Mtoe), nuclear and geothermal energy (each 19 Mtoe higher), wind and solar energy (4 Mtoe) and hydroelectricity (1 Mtoe) (Figure 26).

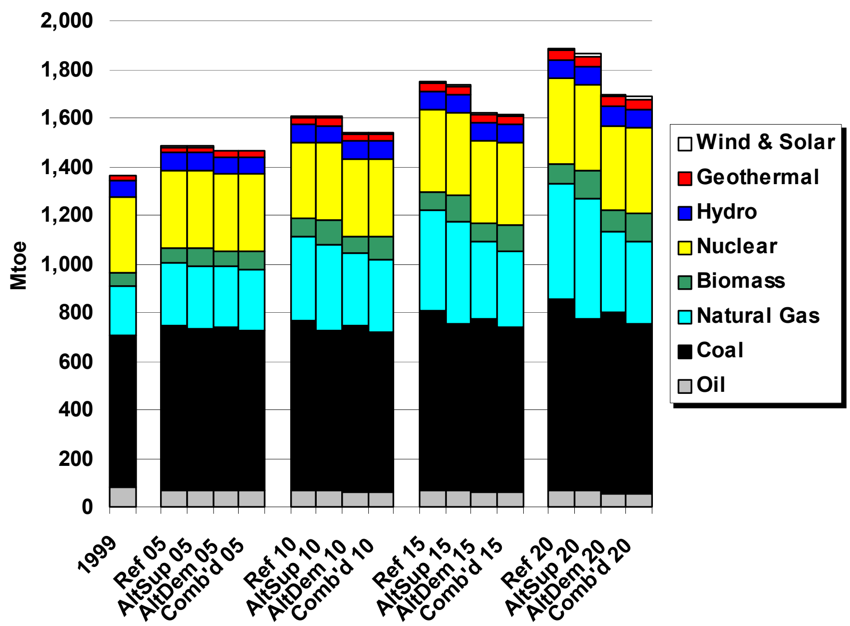
Figure 26 Scenario comparison on inputs for power generation – APEC



Notes: **Ref** – Reference Case, **AltSup** – Alternative Supply Case, **AltDem** – Reduced Demand Case, **Comb'd** – Combined Alternative Supply and Reduced Demand Case. The numbers 05, 10, 15 and 20 refer to 2005, 2010, 2015 and 2020, respectively.

For Group A economies where the demand reduction is highest, 10.7 percent of fuel savings relative to the reference case could be realised. Most of the reduction will come from natural gas at 134 Mtoe, coal 90 Mtoe and oil 12 Mtoe. New and renewable energy will, however, have a higher contribution of 35 Mtoe, mostly from biomass at 33 Mtoe (Figure 27).

Figure 27 Scenario comparison on inputs for power generation – Group A



For Group B, the highest reduction will be from coal at 30 Mtoe, followed by natural gas at 19 Mtoe and oil at 1 Mtoe. Biomass, hydro, wind and solar energy will have a higher contribution of 3 Mtoe to compensate for some of the reductions in coal, natural gas and oil (Figure 28).

Figure 28 Scenario comparison on inputs for power generation – Group B

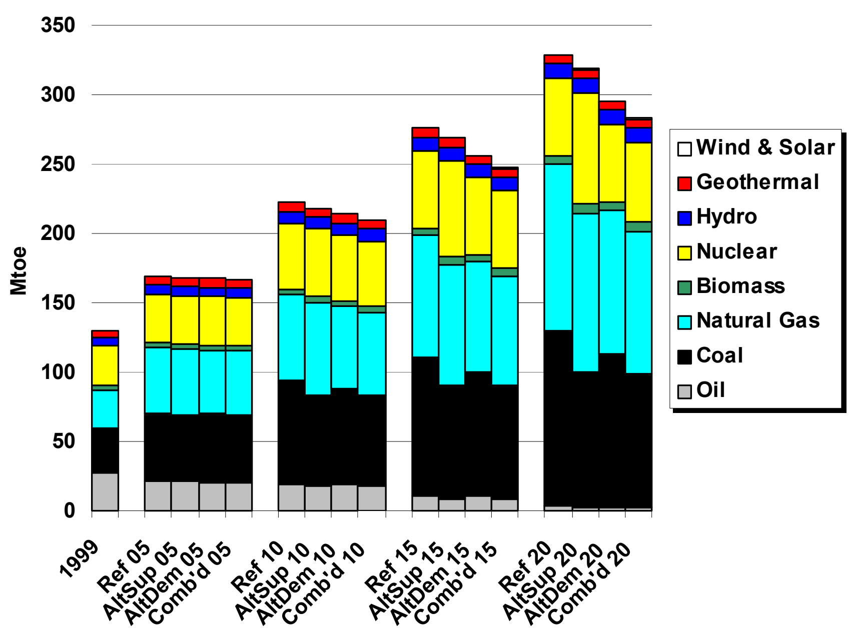
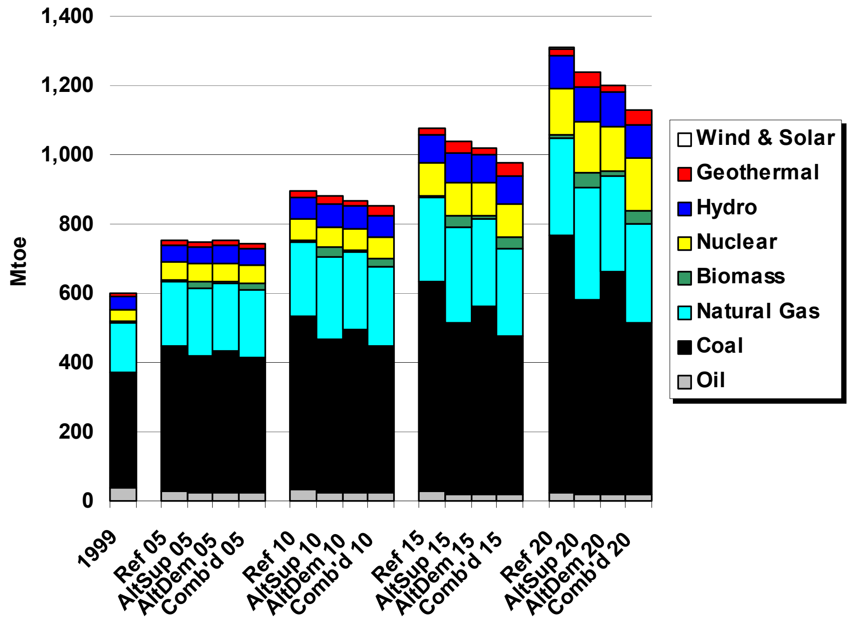


Figure 29 Scenario comparison on inputs for power generation – Group C



In Group C, 251 Mtoe of coal and 3 Mtoe of oil consumption will be avoided with the assumed demand reduction. An additional 6 Mtoe of natural gas, 19 Mtoe of nuclear energy and 50 Mtoe of renewable energy could replace some of the avoided fossil fuel consumption. The total reduction in energy inputs for power generation of 178 Mtoe represents 13.6 percent of the projected total inputs in the reference case.

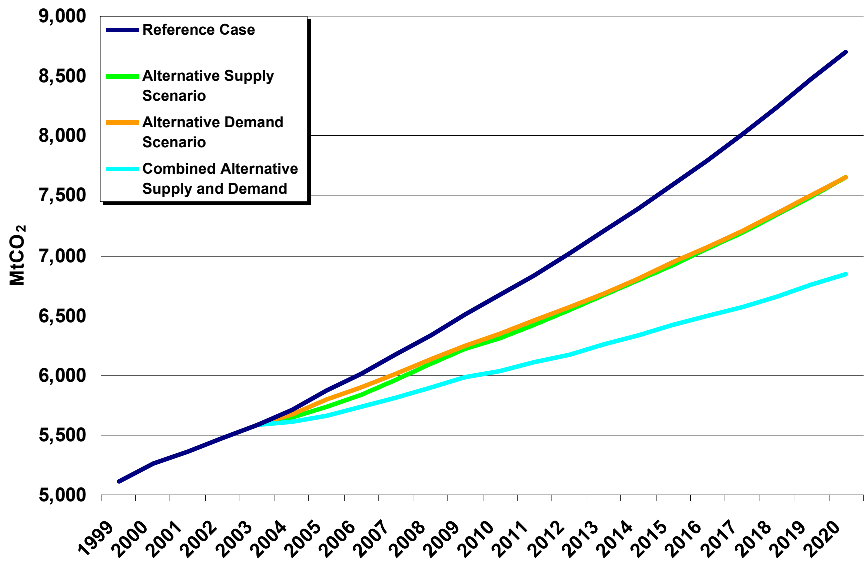
GHG EMISSIONS[68]

With the 3.2 percent annual growth in electricity demand, a consequent annual increase in CO_2 emissions of 2.6 percent is projected in the reference case. It is worth highlighting the slower growth rate in CO_2 emissions compared with demand growth, as it shows that less CO_2 will be emitted for every kilowatt of electricity generated in the future. The slower growth in CO_2 emissions could be attributed to the assumptions of higher efficiency in energy conversion and the higher penetration of fuels with less carbon content like natural gas, and those that have no carbon content like nuclear, geothermal, hydro, wind and solar energy.

Looking at the results of the cases examined, growth in CO_2 emissions could be reduced to 1.9 percent per annum in the alternative supply case, with higher improvement in energy conversion efficiency and the utilisation of environment-friendly energy sources. By reducing demand through DSM, end-use efficiency and cogeneration in the alternative demand case and using the reference supply assumptions, growth of CO_2 emissions could also be reduced to 1.9 percent per annum. Finally, with the reduced demand and using alternative supply assumptions, growth in CO_2 emissions could further be reduced to 1.4 percent per annum (Figure 30). The reduction in emission is 21.3 percent of the reference case.

68 Emissions include carbon dioxide, methane and nitrous oxide, and are expressed as CO_2 equivalent.

Figure 30 Scenario comparison on CO_2 emissions from electricity generation – APEC



In Group A economies, a 1.6 percent annual growth in CO_2 emissions is projected in the reference case. By using alternative supply assumptions, growth could be brought down to 1.2 percent per annum. If demand is reduced in the alternative demand case, CO_2 emissions could grow by 0.9 percent per annum. Applying the alternative supply assumptions and using the reduced demand estimates, emission growth could further be reduced to 0.7 percent per annum (Figure 31). The total reduction from the reference case to the alternative case is as much as 16.8 percent.

Figure 31 Scenario comparison on CO_2 emissions from electricity generation – Group A

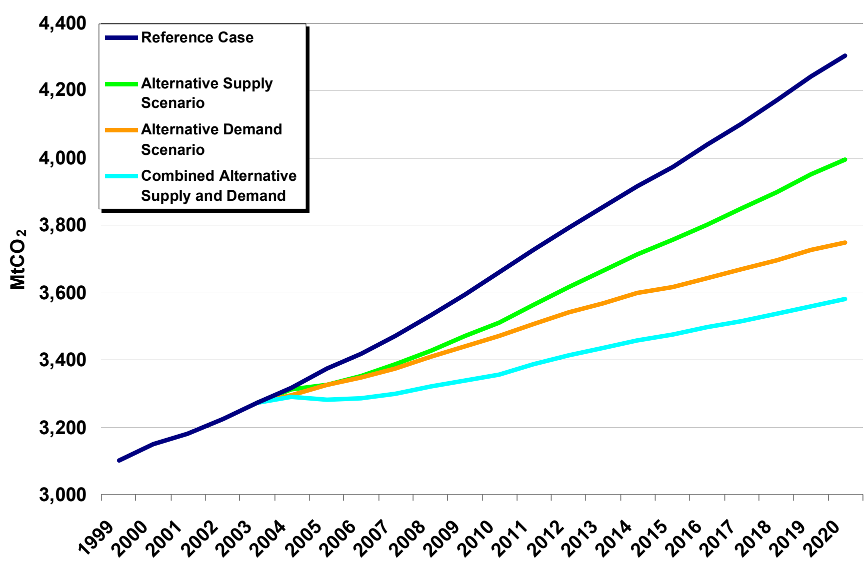
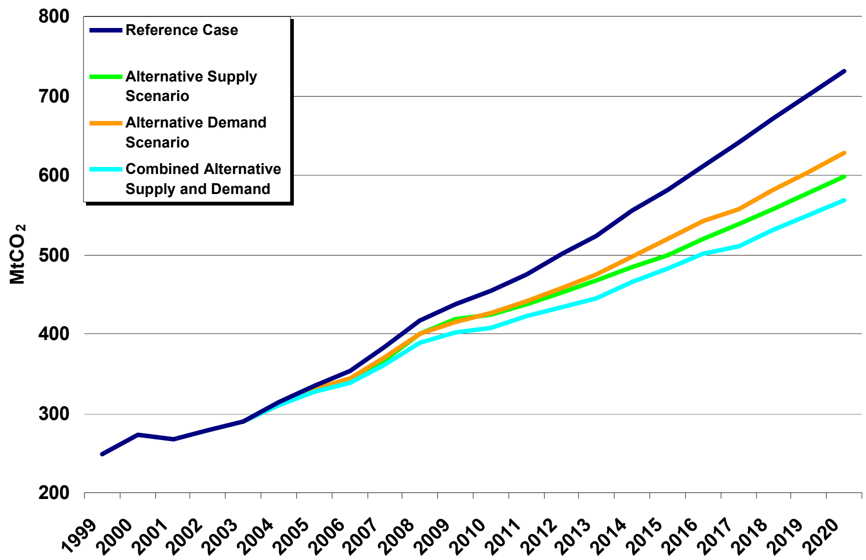
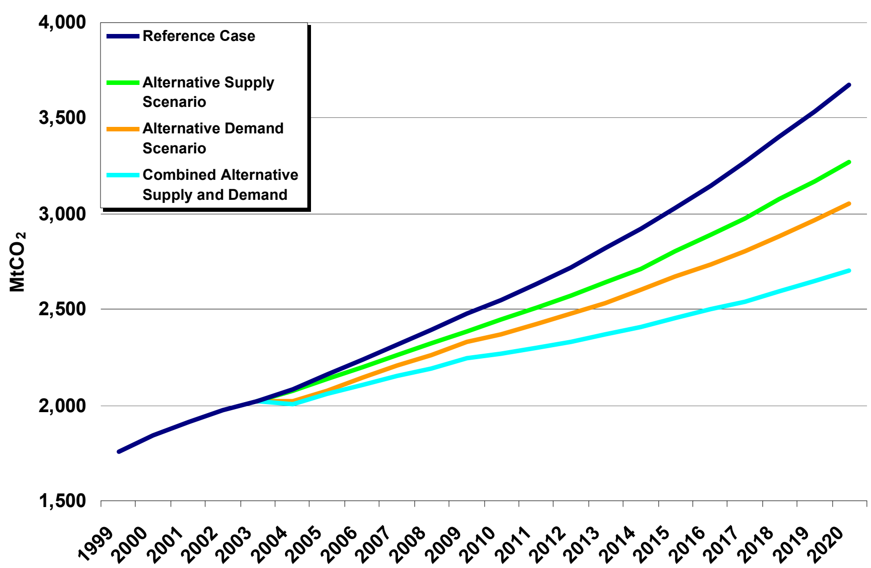


Figure 32 Scenario comparison on CO_2 emissions from electricity generation – Group B



For Group B economies, 22.3 percent of resultant emissions in the reference case could be avoided. By using the alternative supply assumptions alone, growth in emissions could be reduced to 4.3 percent from 5.3 percent in the reference case. Using the reference supply assumptions and the assumed reduced demand, emission growth could be trimmed to 4.5 percent. By applying the alternative supply assumptions to the reduced demand estimates, emission growth could be further reduced to 4.0 percent (Figure 32).

Figure 33 Scenario comparison on CO_2 emissions from electricity generation – Group C



For Group C economies, a higher potential for CO_2 reduction of 26.4 percent from the reference case, which is projected to grow at 3.6 percent per annum, could be realised. The growth of emissions in the reference case could be reduced by 2.7 percent per annum using alternative supply assumptions. With reduced demand and reference supply assumptions, emissions growth could be trimmed to 3.0 percent. Combining the alternative supply and demand assumptions, CO_2 emissions in this economy group could fall to 2.1 percent per annum.

CHAPTER 5

ALTERNATIVE TRANSPORT DEVELOPMENT SCENARIO

INTRODUCTION[69]

Designing an alternative development transport scenario for an economy that is both feasible and compatible with – or at least conducive to – sustainable development is not an easy endeavour. Doing so for each of the 21 very diverse APEC members is an even more challenging task.

The difficulties do not lie in a lack of policies or measures. Countless measures have been implemented with the aim of solving the many problems caused by transport systems, but more often than not they have failed, sometimes even backfiring with respect to the planned objective. A typical example of this is the expansion of road capacity to overcome congestion where, after initial relief, congestion reappears, demanding further capacity expansions in an endless vicious cycle. Or sometimes the measures have achieved their goal, but have had unexpected effects that have worsened other problems.

There is also an abundance of ambitious alternative scenarios that have been proposed but have never materialised, remaining in the realm of wishful thinking; those proposed in this study may well follow the same fate.

To understand why this is so, one must start by recognising that transport is a very complex system that is closely interrelated with other complex systems. As pointed out in a recent APERC report,[70] energy consumption in this sector can be influenced by a variety of economic, social and political factors including technology, lifestyle changes, government policy and urban planning.

Perhaps the wrong questions have been asked: "How can we improve the efficiency of cars?" "How can we reduce the local pollution they cause?" "How can we reduce transport's CO_2 emissions?" "How can we reduce congestion?" "How can we improve mobility?" "How can we prevent or reduce accidents?" These are all questions that can lead to actions that try to solve or at least mitigate a particular problem.

Perhaps we should instead ask basic questions such as: "What are the characteristics of a city that fulfils the accessibility needs of its people?" and "What kind of transport system should that city have?" These questions are not focused on solving problems, but rather on designing a desirable future.

It is evident that policy-makers cannot start from scratch. Transport and city infrastructure – as well as some economies' industrial policies – have an inertia that limits the scope of what is feasible, especially in the short and medium term. However, given current and projected trends, it has also become evident that mere fine-tuning is not enough.

Sometimes the 'solution' to a particular problem has been to eliminate the problem altogether. Today no one forecasts the number of horses needed to carry an increasing population, the amount of food they will need, nor the tons of dung they will produce that will end up inundating the streets.[71] The car replaced the horse and its problems, opening up undreamt of potential, but it also brought along with it a series of other problems. Perhaps some day our current projections of

[69] This chapter draws on a number of sources, including ECMT (2002a, 2002b, 2002c), IEA (1997, 2001e), Litman (2002), OECD (1996, 2002a, 2002b), Peake (1994), WBCSD (2001), and numerous publications from the World Bank, the Institute for Transport Studies of the University of Leeds, and the Victoria Transport Policy Institute.

[70] APERC (2001a).

[71] Peake (1994).

growth of car stocks, the quantity of oil required to make them run, or their CO_2 emissions will seem equally outdated, or at least they may cease to be important issues.

In fact, significant changes in this direction have already begun. All major automakers, many oil companies and some economies are laying the foundations of an energy system based on hydrogen obtained from renewable sources. Even though this will represent a radical improvement with respect to the current situation of transport and energy systems, it will still leave many issues unaddressed. As an illustration, a zero-emission, ultra-efficient, hydrogen-powered fuel cell car may still contribute to congestion, cause accidents, and require significant resources to produce and build the infrastructure necessary to use it. Moreover, given the costs involved, hydrogen-based transport systems do not seem a feasible approach for low- and middle-income APEC economies, at least only in the very long term.

In sum, an alternative development scenario for transport is not about the elimination of cars, requiring everybody to use public transport and non-motorised modes, but rather about designing a transport system that fulfils the needs of its users in a sustainable way and of the policies and measures required to put it in place given its present state. This necessarily far exceeds limited objectives such as improving energy efficiency or reducing emissions of air pollutants.

Such an ambitious task is outside the scope of this study. Thus, this chapter presents only a preliminary estimate of the effects of integrated packages of measures on transport energy consumption and CO_2 emissions of APEC member economies.

APPROACH

The approach used in this study is based on a simplified version of the environmentally sustainable transport (EST) initiative fostered by the Organisation for Economic Co-operation and Development (OECD) since 1994.[72] This project addresses the challenge of maintaining and enhancing transport's benefits while reducing its impacts to sustainable levels. Among the products of this project is a set of 10 guidelines that have been endorsed by OECD environment ministers (see Box 1), as well as a number of case studies. Currently, the project is being extended to non-OECD economies.

The approach used by EST involves setting sustainable transport scenarios or visions, characterising them in terms of quantifiable targets, and lastly, performing a backcasting exercise that involves working back from these targets to present conditions to determine what actions are required to ensure that the targets are met.

This APERC study also incorporates views from the Sustainable Mobility project, launched in April 2000 by the World Business Council for Sustainable Development (WBCSD). WBCSD is formed by some of the world's largest firms in the energy and transport business, including BP, DaimlerChrysler, Ford, General Motors, Honda, Michelin, Nissan, Norsk Hydro, Renault, Shell, Toyota and Volkswagen. The project aims to "show possible pathways towards Sustainable Mobility that will answer societal, environmental and economic concerns" and explore how these firms can contribute to this process.[73]

72 OECD (2002a).

73 WBCSD (2001).

Box 1. EST Guidelines

*"**Guideline 1**. Develop a long-term vision of a desirable transport future that is sustainable for environment and health and provides the benefits of mobility and access.*

***Guideline 2.** Assess long-term transport trends, considering all aspects of transport, their health and environmental impacts, and the economic and social implications of continuing with 'business as usual'.*

***Guideline 3.** Define health and environmental quality objectives based on health and environmental criteria, standards and sustainability requirements.*

***Guideline 4.** Set quantified, sector-specific targets derived from the environmental and health quality objectives, and set target dates and milestones.*

***Guideline 5.** Identify strategies to achieve EST and combinations of measures to ensure technological enhancement and changes in transport activity.*

***Guideline 6.** Assess the social and economic implications of the vision, and ensure that they are consistent with social and economic sustainability.*

***Guideline 7.** Construct packages of measures and instruments for reaching the milestones and targets of EST. Highlight 'win-win' strategies incorporating, in particular, technology policy, infrastructure investment, pricing, transport demand and traffic management, improvement of public transport, and encouragement of walking and cycling; capture synergies (e.g. those contributing to road safety) and avoid counteracting effects among instruments.*

***Guideline 8.** Develop an implementation plan that involves the well-phased application of packages of instruments capable of achieving EST taking into account local, regional, and national circumstances. Set a clear timetable and assign responsibilities for implementation. Assess whether proposed policies, plans, and programmes contribute to or counteract EST in transport and associated sectors using tools such as Strategic Environmental Assessment (SEA).*

***Guideline 9.** Set provisions for monitoring implementation and for public reporting on the EST strategy; use consistent, well-defined sustainable transport indicators to communicate the results; ensure follow-up action to adapt the strategy according to inputs received and new scientific evidence.*

***Guideline 10.** Build broad support and co-operation for implementing EST; involve concerned parties, ensure their active support and commitment, and enable broad public participation; raise public awareness and provide education programmes. Ensure that all actions are consistent with global responsibility for sustainable development."*

Source: Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management/OECD (2000a), page 11.

DEFINITION OF SUSTAINABLE TRANSPORT

Sustainability lies at the core of the EST approach. The following definitions clarify what is meant by a sustainable transport system, and specifically by an environmentally sustainable transport system.[74]

> *A sustainable transport system should provide access to people, places, goods, and services in an environmentally responsible, socially acceptable, and economically viable manner. An environmentally sustainable transport system is one where transportation does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes.*

Several issues are apparent from the above definitions. First, even though sustainability is a very ambitious goal, it is a minimum condition, not an ideal one. The distance that separates current transport systems from this minimum further highlights the enormity of the task to be done. Moreover, sustainability is a dynamic process, not a static goal. Needs evolve and so must sustainable transport systems.

Secondly, the definition stresses access, which is a broader concept than mobility. This means that the focus is not on how to move people or goods from one point to another, but rather on providing the service (work, leisure, information, etc). In other words, transport is mostly a derived demand and not an end in itself. This is an important distinction, which broadens the scope of actions that can be envisaged.

Thirdly, sustainability is based on environmental, economic and social pillars. This means that if one sets targets for just one of the three pillars and merely checks that the implications for the other two lie within acceptable ranges, then one is probably finding local and not global optimums. The approach followed by EST which stresses environmental goals, is obviously not an oversight but rather an indication of the complexity of the transport system and the magnitude of the task that needs to be done.

Fourthly, as can be deduced from the reference case discussed in Chapter 2, current transport trends are, in general, not sustainable. Transport's many problems, including local air pollution, resource utilisation (energy, land, materials), accidents, noise, congestion, climate impacts and others have been widely and repeatedly discussed, so there is no need to explain them further here. It must be noted that significant progress has been achieved in some areas and economies, notably in the reduction of air pollutants. However, there is still much to be done.

Lastly, there is a growing consensus that major changes to 'business as usual' must be put in place in order to achieve sustainability.

ALTERNATIVE SCENARIO TARGETS

The long-term vision of this study is that transport systems of APEC economies be sustainable (environmentally, economically and socially). This is a very ambitious goal that most likely will not be met by 2020, not even by the most developed APEC economies.

Furthermore, though broadly speaking there are many similarities in the trends that the transport sectors of APEC economies are following, the characteristics of these systems in each economy vary widely. Economic development and structure are very different, as are the

[74] Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management/OECD (2000a).

compositions of vehicle fleets, geography, culture, and countless other factors. This means that the issues and the urgency with which they have to be addressed also differ.

Therefore, in order for the proposed scenarios to have at least some degree of achievability by 2020, the general long-term targets outlined below are not applied equally to all economies, either with respect to the main issues to be addressed or the degree of compliance by that year.

For simplicity, the goals and targets are divided according to the three pillars of sustainability: environmental, economic and social. However, some goals and targets classified under one pillar may also apply to the other two. Environmental targets basically follow World Health Organization (WHO) guidelines (which may become more stringent in the future). Economic and social targets are harder to define quantitatively, and require further discussion.

Table 16 Sustainable transport goals and long-term targets

Goals	Long-term targets
ENVIRONMENTAL AND HEALTH	
Acceptable noise levels	WHO guidelines attained. Depending on local and regional conditions, noise levels should be no more than 55 dB(A) during the day and 45 dB(A) at night and outdoors.
Acceptable air quality	WHO guidelines attained for NO_x, volatile organic compounds (VOCs) and other air pollutants. Elimination of leaded gasoline. Though WHO does not have guidelines for PM_{10} and $PM_{2.5}$, a preliminary target is a 50-99% reduction of emissions depending on local and regional conditions.
	Acceptable levels of ozone attained. Reduction of 80% of NO_x and VOC emissions.
Critical loads attained with respect to acidification/eutrophication	Reduction of 75-95% of SO_x and NO_x emissions (-50% NH_3).
Climate protection. Stabilisation of GHG concentrations	Reduction of GHG/CO_2 emissions by 80% for APEC OECD economies and 50% for non-OECD economies.
Acceptable land-use/land-take	Land-use and in particular infrastructure for the movement, maintenance and storage of transport vehicles is developed in such a way that local and regional objectives for air, water and ecosystem protection are met.
ECONOMIC	
Sustainable use of resources	Use of renewable resources within their rates of regeneration and use of non-renewable resources within the rates of development of renewable substitutes. Recycling of 100% of materials used in road vehicles, planes, ships and trains. External costs are internalised, with users paying the full cost derived from their use of the system.
Financial viability	Positive private and/or social net present value, that ensures availability of resources for the financial viability of the system.
Absence of congestion	A balance between available capacity and the traffic that attempts to use it at a given time.

Goals	Long-term targets
SOCIAL	
Access to people, places, and goods and services as needed	Appropriate infrastructure is in place.
Equity of access	Equity of access to goods and services, especially for the poor, the elderly, the disabled and the young.
Safety and security	No accidents. No threats to personal security.
Disruption of communities	Impacts of transport infrastructure and use do not surpass acceptable levels of disruption to communities or to natural habitats.

Note: Reductions are based on 1990 levels.

Source: Mostly based on Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management/OECD (2000b) and WBCSD (2001).

POLICIES AND MEASURES TO ACHIEVE THE TARGETS

Many parallels can be made between transport and electricity systems.[75] The approaches towards policy-making and measures that have been applied have followed more or less the same path, with electricity leading the way. For many decades the focus was solely on supply expansion and technology. By the latter quarter of the 20th century it became apparent that this was not enough, and demand-side policies and 'soft' measures were put in place. Environmental concerns shaped policies in both sectors during this period, with an initial focus on controlling emissions. Since then, sustainability concerns have caused policy-makers to reconsider the fundamentals of each system, to see where major changes may be needed.

As indicated in Guideline 7 of the EST Guidelines – which build on the positive and negative experiences of the last few decades – an integrated approach is needed to construct packages of measures to reach the intended targets. Packages typically contain regulatory, fiscal, investment and educational measures. These packages must be tailored to the specific conditions of the system (Guideline 8) and, as highlighted in Guideline 7, should "capture synergies and avoid counteracting effects among instruments."[76]

It must be stressed that there will be different achievement rates for the targets summarised in Table 16. Three targets in particular, namely the 50/80 percent reduction in CO_2 emissions, sustainable use of resources and the elimination of accidents, are not expected to be reached by any APEC economy by 2020, and probably not even by 2050. Likewise, social goals may have varying degrees of compliancy by 2020, especially in developing economies.

It should also be remembered that the measures proposed are in addition to those considered in the reference case. This can mean that new measures are applied in a certain economy, or that an existing measure is enhanced.

The following table summarises the measures considered in the alternative scenario. For each economy, a package of measures was designed taking into consideration its particularities.

75 Peake (1994).

76 Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management/OECD (2000a).

Table 17 Measures considered in the alternative transport scenario

Type of measure	Measures
Regulatory	Fuel efficiency standards
	Emissions standards and inspections
	Parking management and fees
	Transport management (HOV/HOT and exclusive lanes, traffic calming, priority for public transport, etc)
	Fuel quality regulations (sulphur, lead, etc)
	Regulations for noise, including restrictions
	Safety standards
	Recycling requirements for vehicles
	Enforcement of traffic regulations
	Environmental regulation for infrastructure expansion
	Harmonisation of standards (emissions, fuel efficiency)
	International agreements with vehicle manufacturers (including voluntary agreement to reduce specific CO_2 emissions of cars to 140 g CO_2/km by 2008 and 120 g CO_2/km by 2012)
	Regulation for vehicle to grid (V2G) interconnection
Fiscal	Road/congestion pricing
	Variabilise fixed costs ('pay-at-the-pump' insurance, etc)
	Feebates to promote low-emission and energy-efficient vehicles
	Incentives for alternative fuels
	Internalisation of external costs
	Incentives for employees
	Incentives for scrapping old vehicles
	Fuel tax
Regulatory and fiscal	Urban planning/land use regulations and incentives
	Tradable CO_2 permits
	Fleet maintenance and renewal incentives and regulations
Investment	Promotion of public transport
	Support for non-motorised modes (pedestrians and cycling)
	Infrastructure expansion and improvement (roads, railways, airports, ports, telecommunications; includes information systems, road traffic management systems, accessibility for the disabled and elderly, integration of public transport networks, etc)
	Network of urban distribution centres
	Facilitate inter-modal freight transport
	Investment to improve fuel quality (reduction of sulphur, etc)
	Support for fuel cell development
	Investment in alternative fuel supply
Educational and hortatory	Consumer information on efficient and low-emission vehicles (labelling, real-time fuel economy, etc)
	Individualised marketing programmes and other demand reduction programmes
	Training of drivers
	Travel information systems

Type of measure	Measures
	Employer-sponsored trip-reduction programmes
	Public participation in city and transport planning
	Dissemination of best practices

Source: Mostly based on OECD (2002b).

ASSUMPTIONS

The main assumptions made in the alternative transport scenario were the following:

- Transport planning is done in close coordination with all related sectors, especially with urban planning. In some economies, this may require streamlining and reorganisation of entities that currently deal with different aspects of transport planning, investment and operation in an uncoordinated and sometimes contradictory manner. There is strong public participation from the early stages of the planning process.
- International harmonisation of standards for vehicle emissions, fuel economy and safety is achieved before 2005. This gives the vehicle industry a clear roadmap and time that will increase the potential market for more efficient and cleaner vehicles. Vehicles that comply with stricter standards start entering the market in 2010. Adoption dates of fuel economy standards vary according to the conditions in each economy. In particular, the US adopts stricter fuel economy standards in 2010. The adoption of stricter emissions standards (such as Euro IV) in some economies is done ahead of the currently planned dates.
- Investment in supply of cleaner fuels is done in time to allow the introduction of vehicles that require such fuels.
- There is strong investment in public transport, especially in those economies where it has a high but declining share of passenger-kilometres. The system satisfies the needs of its customers and is a real alternative to private transport. Bus Rapid Transit (BRT)[77] is adopted in many economies given its favourable balance of relatively low cost, adequate passenger movement capacity and high service quality. There is fare and route integration between modes. Non-motorised transport is made attractive for short distances.
- Demand-side measures are actively pursued throughout the period to increase the efficiency of the transport system. The measures begin to have an effect in 2004. In some economies, measures are as basic as enforcement of existing traffic laws or introduction of parking charges. Starting in the second half of this decade, many economies will implement congestion pricing, transform fixed costs into variable charges, and take other fiscal measures that make costs more visible to users of the transport system, especially to car owners. Measures in the freight sector include efficiency improvements in distribution systems and increasing the attractiveness of intermodal freight transfers.
- Internalisation of external costs is increasingly pursued by governments and has an appreciable effect after 2010.

77 BRT has been implemented or there are plans to implement it in cities of many APEC economies, such as Kunming, Taipei and Santiago. The alternative scenario assumes a much higher adoption rate.

- Ratification of the Kyoto Protocol in the first half of this decade spurs CO_2 emissions trading markets and technology transfer. The transport sector becomes attractive for transactions related to climate change after 2010.
- The share of fuel cell cars and buses in Canada, Japan, Korea, Singapore and the US with respect to the total car and bus stock is given an additional boost of 2 to 5 percent after 2015, compared with the reference case.
- Hydrogen for fuel cell cars and buses is obtained from renewable sources, and not from gasoline or natural gas as in the reference case.
- Regulation is put in place to facilitate the connection of electric-drive vehicles to the grid (V2G). The commercial attractiveness of these vehicles is enhanced by the capacity to sell services such as peak load power and spinning reserve, and their ability to act as power regulation units.
- Regulatory, fiscal and other measures on air transport, which could include a tax on jet kerosene, start to have an effect on energy consumption by 2015.

ANALYTICAL RESULTS

The following sections summarise the results of the alternative development scenario for transport in terms of energy consumption and GHG emissions, for APEC as a whole and for each economy grouping.

ENERGY CONSUMPTION

Results of the alternative scenario show that transport energy consumption in the APEC region could amount to 1,366 Mtoe in 2020, which would be 25 percent less than the reference case, or roughly 45 percent of APEC's transport energy consumption in 1999 (see Figure 34). Approximately 97 percent of projected savings will come from reductions in the road sub-sector, and nearly 3 percent from air transport. Consumption by marine navigation will increase marginally (by 1 Mtoe). Cumulative oil consumption savings in 2004-20 are estimated to reach nearly 26 billion barrels, worth US$608 billion.[78] Nearly 73 percent of total transport energy savings in APEC are projected to come from Group A economies, while Groups B and C will account for 9 and 18 percent, respectively. The US is projected to account for 59 percent of total savings, followed by China with 9 percent and Japan 5 percent. Changes in energy consumption in 2020, compared with the reference case, range from -36 percent for the US to +15 percent for Papua New Guinea, with most economies falling in a range of -10 to -30 percent. This is a result of different packages of measures applied to each economy, in turn reflecting different conditions and energy efficiency potentials in each of them.

In general, the measures that are expected to have the greatest impact are fuel efficiency standards, the internalisation of external costs (through various measures such as congestion pricing, and parking restrictions and charges), transforming fixed costs into variable costs, investment in efficient and attractive public transport, and demand management (both in the road passenger and freight sub-sectors). In the long run, urban planning is expected to make an important contribution to reducing energy consumption while improving accessibility levels. CO_2 emissions trading after 2010, first in developed economies and later in developing ones, could provide a significant impetus to achieve less energy-intensive and more environmentally friendly transport systems. In some high-income economies such as Canada, Japan, Korea, Singapore and

[78] Calculated using yearly oil price projections provided by DRI-WEFA. For details, see APERC (2002a).

the US, the effect of fuel cell vehicles in reducing oil demand is projected to be noticeable towards the end of the forecast period.

Figure 34 Scenario comparison on transport energy consumption – APEC

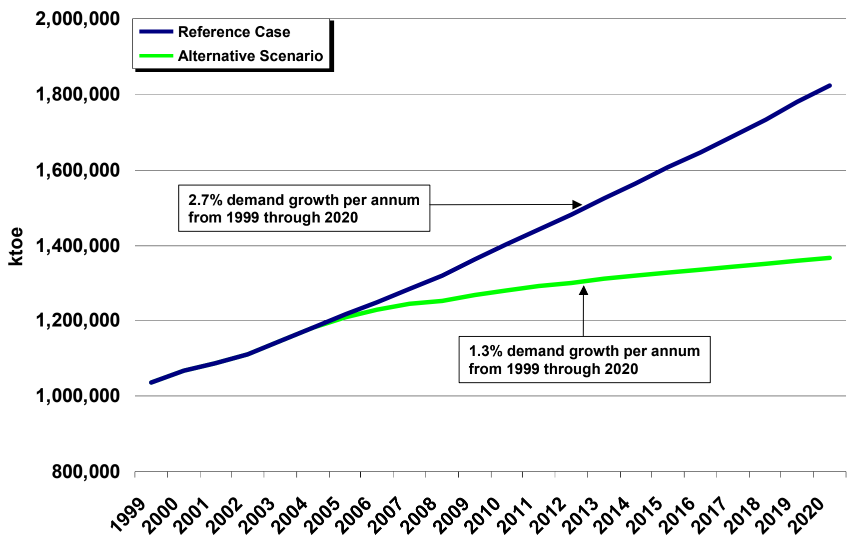
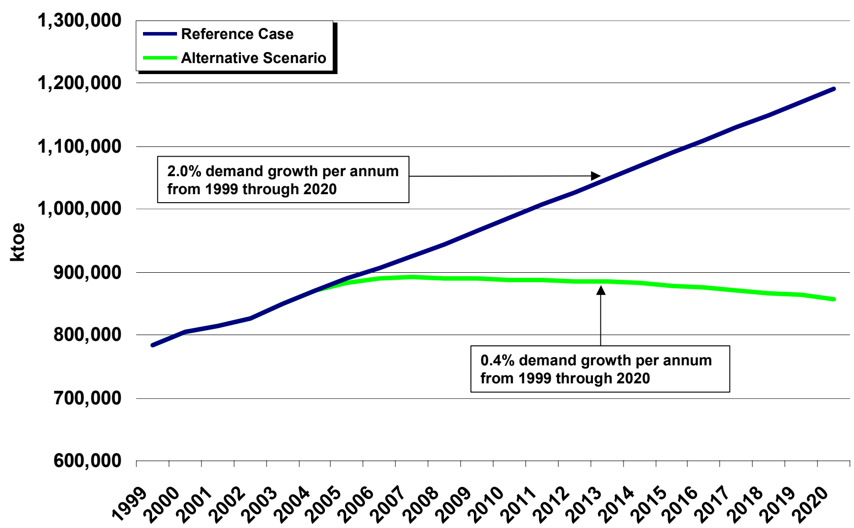


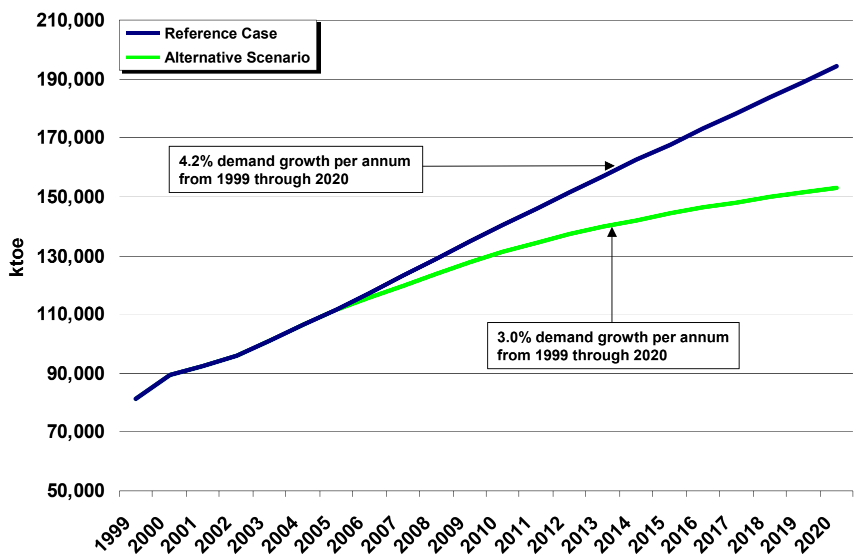
Figure 35 Scenario comparison on transport energy consumption – Group A



Economies in Group A are projected to reduce energy consumption growth for the period 1999-2020 from an annual average rate of 2.0 percent in the reference case to 0.4 percent in the alternative scenario. This translates into a 28 percent reduction between the two scenarios in 2020, equivalent to 334 Mtoe (see Figure 35); this is the biggest reduction of the three economy groups, in both absolute and percentage terms. Moreover, this group is the only one in which energy consumption is expected to decline, after peaking in the second half of this decade. The fastest reductions are expected to occur after 2015 (-0.5 percent per annum on average), mainly due to the increased share of high-efficiency vehicles, particularly fuel cell vehicles. Energy consumption in road transport in 2020 is projected to be 11 percent below the 2004 level (compared with 34 percent higher in the reference case). The biggest increase will be in air transport, which will be 51 percent higher than in 2004 (compared with 59 percent higher in the reference case).

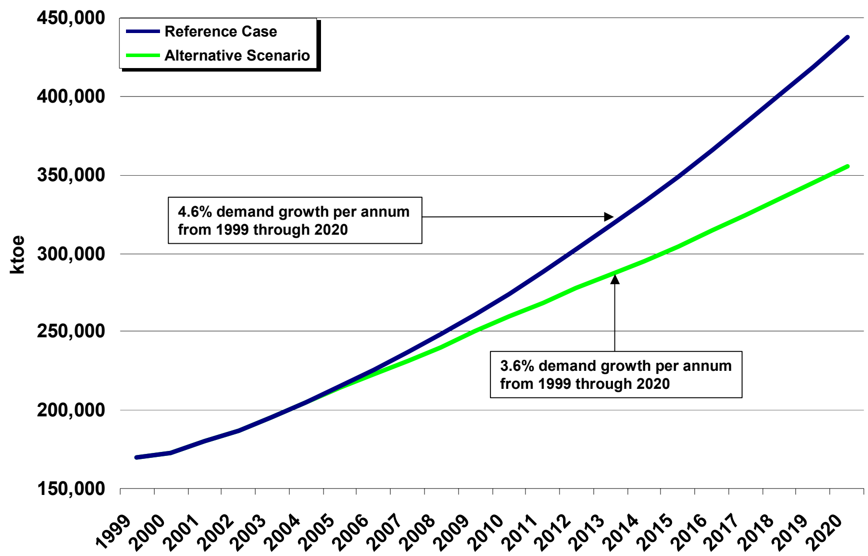
Average annual growth in energy consumption for Group B economies during the period 1999-2020 is projected to reach 3.0 percent in the alternative scenario, down from 4.2 percent in the reference case. This represents a 21.3 percent reduction between the two scenarios in 2020, equivalent to 41 Mtoe (see Figure 36), or roughly half of this group's consumption in 1999. As in other groups, road transport is projected to account for over 97 percent of the savings compared with the reference case, while air transport will account for most of the remainder. Road transport energy consumption in 2020 is expected to be 31 percent higher than in 2004 (compared with 77 percent higher in the reference case). This is a result of reductions due to efficiency improvements, which will be partially offset by increases in public transport services.

Figure 36 Scenario comparison on transport energy consumption – Group B



Group C economies will experience the fastest growth in energy consumption of the three groups, at an annual average rate of 3.6 percent for the forecast period, down from 4.6 percent in the reference case. The 18.9 percent difference in energy consumption between the two scenarios in 2020 amounts to nearly 83 Mtoe (see Figure 37), or roughly half of this group's consumption in 1999. Strong investment in and expansion of public transport is expected to partially offset reductions in road energy consumption due to technological and operational efficiency improvements. Energy efficiency and emissions standards for vehicles are expected to play a key role in the economies of this group, given a rapidly increasing stock. Equally important will be transport management and land use planning, due to the rapid expansion of urban centres in this group.

Figure 37 Scenario comparison on transport energy consumption – Group C



GHG EMISSIONS[79]

Simulations show that the targets in Table 16 for CO_2 reductions by 2020 could be achieved only by making unrealistic assumptions, and therefore these targets were not taken as a limiting factor. CO_2 emissions in the alternative scenario are expected to increase at a slower rate than energy consumption in all three groups, while the opposite was forecast in the reference case. For APEC, the average annual growth rate of CO_2 emissions in 1999-2020 is expected to reach 1.2 percent, compared with 2.8 percent in the reference case (see Figure 38). Thus, emissions in 2020 could be lower by 27.3 percent or 1,461 $MtCO_2$ than in the reference case. This figure is 48 percent of total transport emissions in 1999.

With the implementation of measures considered in the alternative scenario, economies in Group A, particularly the US and Japan, are expected to account for almost 74 percent of reductions in CO_2 emissions in APEC's transport sector, a slightly higher percentage than this group's share in energy savings (73 percent). As shown in Figure 39, CO_2 emissions are expected to begin a downward trend before 2010, and by 2020 they could be 30.8 percent lower than in the reference case, and at the same level as in 2002. The main contributing factors to this decline are reduced energy consumption due to efficiency improvements, and changes in the energy mix. The share of oil products in the alternative scenario will decrease to 93.7 percent of total energy consumption in 2020 (compared with 98.6 percent in the reference case), down from 99.4 percent in 1999. Hydrogen obtained from renewable sources is expected to account for 37.1 Mtoe or 4.3 percent of this group's transport energy consumption in 2020. Electricity consumption in the alternative scenario is projected to reach 3.5 Mtoe, a figure 699 ktoe higher than in the reference case, while natural gas consumption will reach 1,964 ktoe, 84 ktoe higher than in the reference case.

79 Emissions include carbon dioxide, methane and nitrous oxide, and are expressed as CO_2 equivalent.

Figure 38 Scenario comparison on transport CO_2 emissions – APEC

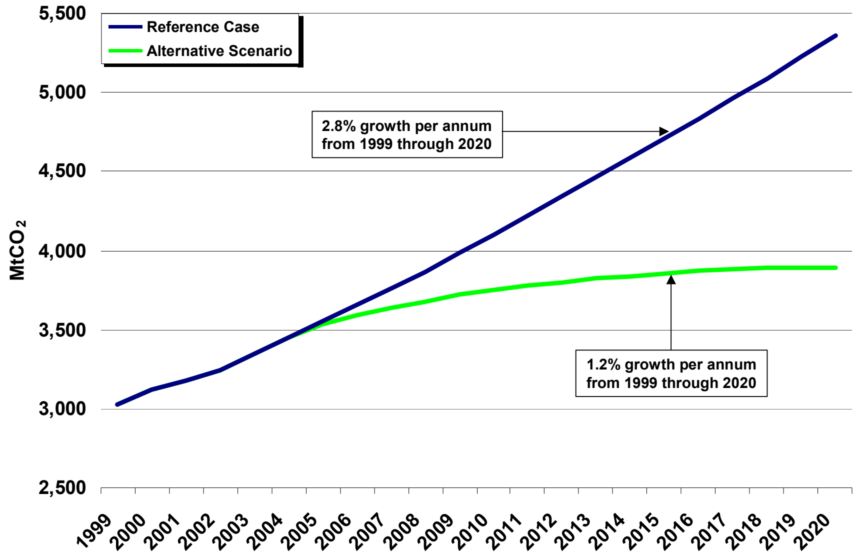
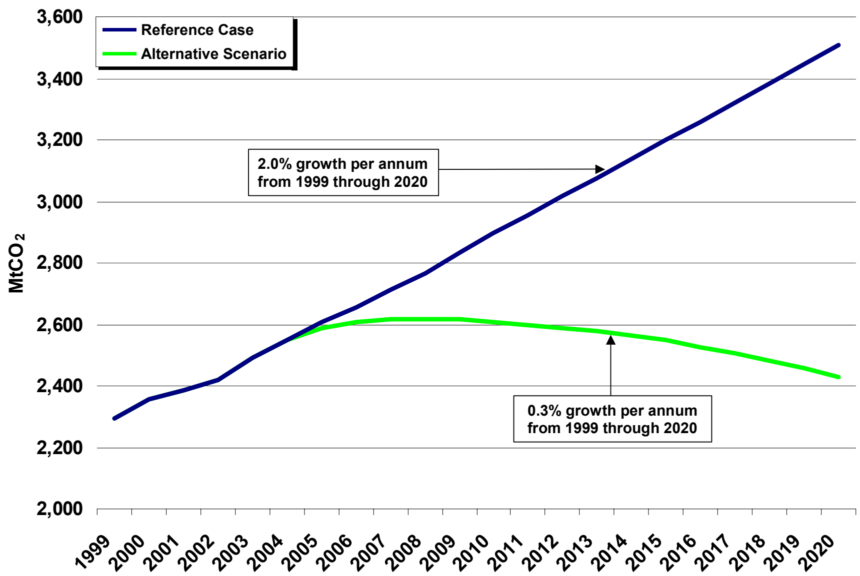
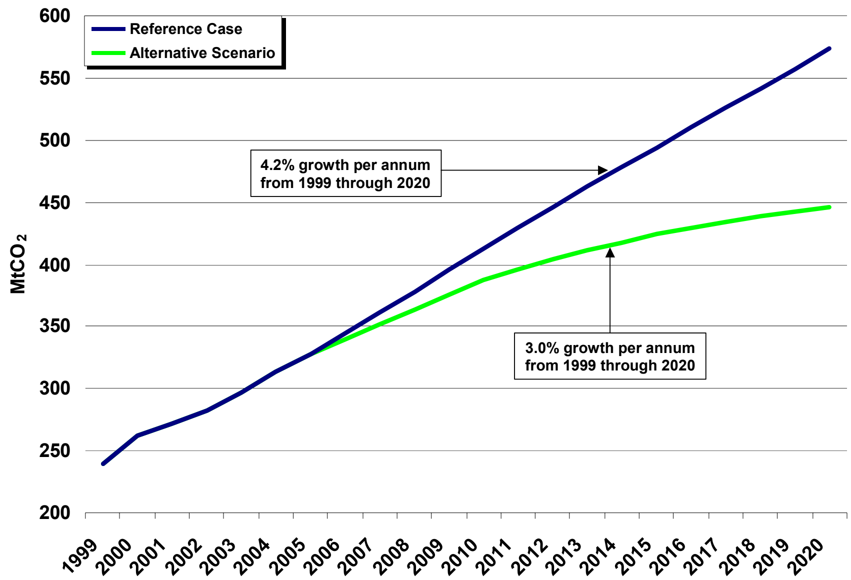


Figure 39 Scenario comparison on transport CO_2 emissions – Group A



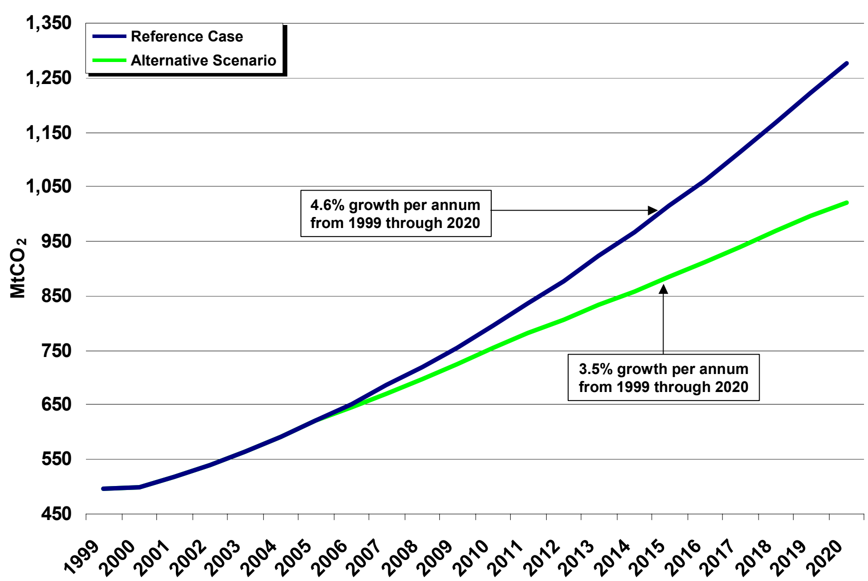
For Group B economies, 22.1 percent of CO_2 emissions in the reference case could be avoided with the implementation of measures considered in the alternative scenario (see Figure 40). Although the latter considers higher consumption of electricity and natural gas than in the reference case, the share of oil products is expected to decrease from 99.7 percent in 1999 to 97.3 percent in 2020, 1.6 percentage points lower than in the reference case. Hydrogen obtained from renewable sources is considered in Korea's measures to reduce CO_2 emissions.

Figure 40 Scenario comparison on transport CO_2 emissions – Group B



CO_2 emissions in Group C economies in the alternative scenario could be 20 percent lower than in the reference case (see Figure 41). Savings are expected to come almost entirely from reduced energy demand, as the share of oil products in 2020 (95.6 percent) is expected to be only two percentage points lower than in the reference case.

Figure 41 Scenario comparison on transport CO_2 emissions – Group C



CHAPTER 6

CONCLUSIONS

The *APEC Energy Demand and Supply Outlook 2002* concluded by stating that "The future depends on the choices we make today, and responsibility will follow. With strong resolve and close cooperation among APEC economies, sustainable energy for the future will be achieved."[80]

In this study we have taken this challenge and explored alternative scenarios for electricity and transport, two key sectors identified in the Outlook. The main driving force behind the scenarios is the achievement of sustainable development.

The alternative scenarios considered a number of challenging but feasible policies and measures that APEC economies can apply. Combined results of the two sectors show that in 2020 APEC could consume nearly 17 percent less energy (equivalent to 884 Mtoe) and emit 24 percent less GHG (amounting to 3,318 $MtCO_2$) than in the reference case, with better environmental performance and improved service. Group A economies are projected to account for nearly 61 percent of total reductions of fuel consumption and 54 percent of emissions. The expected shares of Group B economies could amount to nearly 10 and 9 percent of the total, respectively, while those of Group C are estimated at 30 and 37 percent. By sector, electricity is projected to account for 48 percent of reductions in fuel consumption and 56 percent of reductions in GHG emissions, while transport will account for the remainder. Cumulative reductions of oil consumption in 2004-20 in transport alone could amount to nearly 26 billion barrels, worth US$608 billion.

The achievement of these results will require policy changes together with sustained and concerted efforts among APEC economies. The active involvement of and cooperation between government, industry, citizens and research institutions is essential.

In the electricity sector, proactive policies on energy efficiency, on both the demand and supply sides, should be improved to be able to attain optimum environmental as well as economic benefits while meeting growing demand for electricity. A key area is the removal of market barriers to achieve wider adoption of demand-side energy efficiency technologies and measures.

Similarly, on the supply side greater impetus should be given to options such as cogeneration, new and renewable energy, and less carbon-intensive fuels, including natural gas and nuclear. Policies should be developed on wind energy – which in many locations has become cost-competitive with conventional power facilities – and on solar home applications. This is where technology learning could help in reducing the cost of these systems and thus making them more competitive. A significant increase in the contribution of biomass could be achieved, for example, through co-firing in coal power plants. There are also potentials for development of small hydro, which could become cost-competitive in certain areas. The same could be said for geothermal potential.

In the transport sector, though there has been progress in the reduction of emissions, many trends are leading to a less sustainable future. Reversing these trends will pose a major challenge to APEC economies.

Most developing economies are experiencing rapid growth in vehicle ownership levels (mainly cars, but also two-wheelers, especially in Asia). Cars promise greater convenience, but as saturation levels are reached it becomes increasingly inconvenient to use them. More importantly, they are imposing increasing costs on society as a whole (pollution, congestion, accidents, use of resources, etc), costs that are only partly borne by users. On the other hand, usage levels of public transport are in general decreasing, in great part because it does not meet the needs of its users.

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80 APERC (2002a).

However, as discussed in this report, a sustainable transport system far exceeds limited objectives such as reducing pollution and fuel consumption, or favouring public transport at the expense of cars. Rather, "a sustainable transport system should provide access to people, places, goods, and services in an environmentally responsible, socially acceptable and economically viable manner."[81]

Policy-makers can play an important role in achieving a more sustainable transport system, resulting in a win-win situation where accessibility levels and user satisfaction are improved, while costs and negative impacts are reduced. Given the global nature of the transport industry, international cooperation is considered critical in a number of areas, including harmonisation of fuel economy and emissions standards, transfer of vehicle technologies, sharing of best practice experience, and the long-term goal of building a transport system in which reliance can be placed on hydrogen-fuelled vehicles.

A number of regulatory, fiscal, investment and educational policies and measures are available to achieve the goals and targets of a more sustainable transport system. A key consideration is that the packages of policies and measures should have synergy, be comprehensive, tailored to the conditions of the location, have an adequate time frame for implementation and involve relevant stakeholders from the early stages of the planning process.

Though individual conditions vary widely, the experience of other economies – both within and outside of APEC, and both positive and negative – can provide valuable input when deciding which policies and measures to apply, and how to apply them. For example, the experiences of Japan, Malaysia, Thailand and the US can assist other economies on how to overcome barriers that hinder the implementation of demand-side energy efficiency and cogeneration. In the transport sector, Singapore has probably the most comprehensive set of policies and measures in the world. From outside of APEC, the cities of Curitiba in Brazil and Bogotá in Colombia provide lessons on how a well-planned transport system centred on the needs of the people can radically improve the quality of life of its users.

It is our hope that this study will contribute to the long-term goal of achieving sustainability in these key sectors of electricity and transport in the APEC region.

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81 Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management/OECD (2000b).

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ANNEX I

ASSUMPTIONS IN THE ALTERNATIVE ELECTRICITY SCENARIO

Table 18 Assumptions in the alternative electricity supply scenario per economy

Economy	Energy	Reference Case	Alternative Supply Scenario
Australia	Oil	No reduction in oil-based capacity	Reduction of oil-based capacity by 5% annually
	Coal	5,326 MW additional capacity by 2020	1,126 MW additional capacity
	Natural Gas	9,348 MW additional capacity	14,348 MW additional capacity
	Wind	1,500 MW by 2020	Additional 500 MW
	Solar	29 MW by 2020	100 MW by 2020
Brunei Darussalam	Solar	0 MW by 2020	10 MW by 2020
Canada	Biomass	1,000 MW by 2020	Additional 1,000 MW
	Solar	375 MW by 2020	700 MW by 2020
	Wind	1,200 MW by 2020	2,400 MW by 2020
Chile	Hydro	2% growth in capacity from 2010	3% growth in capacity from 2010
	Wind	2 MW by 2020	100 MW by 2020
	Solar	0 MW by 2020	100 MW by 2020
China	Nuclear	20,000 MW by 2020	30,000 MW by 2020
	Coal	206,000 MW addition up to 2020	72,000 MW less than Reference Case
	Natural Gas	77,000 MW addition up to 2020	37,000 MW more
	Wind	1,000 MW by 2020	Double Reference Case value
	Solar	2,000 MW by 2020	Double Reference Case value
Hong Kong, China	Solar	75 MW by 2020	Double Reference Case value
Indonesia	Coal	31,400 MW by 2020	5,400 MW less
	Natural Gas	19,000 MW by 2020	3,000 MW more
	Geothermal	978 MW by 2020	1,500 MW by 2020
	Solar	0 MW by 2020	100 MW by 2020
Japan	Coal	46,500 MW by 2020	3,900 MW less
	Natural Gas	64,000 MW by 2020	1,000 MW more
	Wind	4,900 MW by 2020	6,000 MW by 2020
	Solar	7,900 MW by 2020	10,000 MW by 2020
Korea	Coal	43,800 MW by 2020	7,200 MW less
	Natural Gas	41,100 MW by 2020	6,600 MW less
	Hydro	6,600 MW by 2020	6,900 MW by 2020
	Solar	18 MW by 2020	518 MW by 2020
Malaysia	Coal	11,500 MW by 2020	7,000 MW less
	Biomass	200 MW by 2020	300 MW more
	Natural Gas	26,200 MW by 2020	7,000 MW more

Table 18 Assumptions in the alternative electricity supply scenario per economy (cont.)

Economy	Energy	Reference Case	Alternative Supply Scenario
Mexico	Coal	19,000 MW by 2020	2,000 MW less
	Natural Gas	72,900 MW by 2020	1,900 MW more
	Biomass	1,000 MW by 2020	Double Reference Case value
	Wind	1,000 MW by 2020	Double Reference Case value
	Solar	20 MW by 2020	100 MW by 2020
New Zealand	Biomass	170 MW by 2020	310 MW by 2020
	Wind	225 MW by 2020	500 MW by 2020
	Solar	0 MW by 2020	31 MW by 2020
Papua New Guinea	Oil	330 MW by 2020	230 MW by 2020
	Hydro	400 MW by 2020	650 MW by 2020
Peru	Wind	52 MW by 2020	100 MW by 2020
	Solar	3 MW by 2020	5 MW by 2020
Philippines	Coal	10,500 MW by 2020	3,000 MW less
	Natural Gas	5,500 MW by 2020	2,000 MW more
	Geothermal	3,000 MW by 2020	1,100 MW more
	Biomass	40 MW by 2020	500 MW by 2020
	Wind	317 MW by 2020	500 MW by 2020
	Solar	20 MW by 2020	42 MW by 2020
Russia	Oil	45,000 MW by 2020	5,800 MW less
	Coal	88,000 MW by 2020	15,000 MW less
	Natural Gas	101,500 MW by 2020	16,500 MW more
	Hydro	53,600 MW by 2020	3,200 MW more
	Wind	19 MW by 2020	46 MW by 2020
	Solar	100 MW by 2020	500 MW by 2020
Singapore	Biomass	150 MW by 2020	200 MW by 2020
	Solar	0 MW by 2020	40 MW by 2020
Chinese Taipei	Coal	22,500 MW by 2020	1,400 MW less
	Natural Gas	28,200 MW by 2020	1,200 MW more
	Wind	200 MW by 2020	500 MW by 2020
	Solar	150 MW by 2020	300 MW by 2020
Thailand	Coal	13,000 MW by 2020	3,000 MW less
	Natural Gas	27,800 MW by 2020	1,800 MW more
	Biomass	1,900 MW by 2020	3,000 MW by 2020
	Solar	375 MW by 2020	750 MW by 2020
USA	Coal	361,500 MW by 2020	19,100 MW less
	Natural Gas	276,700 MW by 2020	17,500 MW more
	Solar	7,200 MW by 2020	7,400 MW by 2020
Viet Nam	Geothermal	0 MW by 2020	200 MW by 2020
	Wind	0 MW by 2020	20 MW by 2020
	Solar	0 MW by 2020	20 MW by 2020

ANNEX II

CLIMATE CHANGE NEGOTIATIONS[82]

In December 1990 the UN General Assembly convened negotiations which were later to become the United Nations Framework Convention on Climate Change. The convention was adopted in May 1992 and entered into force in March 1994 after the required 50 ratifications were received. The Convention now has 186 Parties. The convention's key objective is the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Under the convention both Annex I (consisting mainly of OECD economies but excluding Mexico and South Korea) and non-Annex I countries (generally described as developing countries), agreed to a general commitment to address climate change, adapt to its effects, and report on the actions they are taking to implement the Convention. In addition to the above commitments, developing countries also agreed to adopt national policies and measures to mitigate climate change.

In December 1997 the Kyoto Protocol was adopted at the third Conference of the Parties (COP). Under the Kyoto Protocol, developed countries (those listed in Annex B of the Protocol) agreed to reduce the sum of their emissions to 5.2 percent below the 1990 level by the period 2008-12. To achieve this reduction, individual countries also agreed on national targets.

For the Protocol to enter into force and become legally binding on ratifying Parties, it requires 55 Parties to the UNFCCC, representing at least 55 percent of 1990 Annex B emissions, to ratify the Protocol. As of December 2002, 17 APEC economies had signed the Protocol and 11 had ratified, approved or accepted it. The entry into force of the Protocol at this date was basically depending on its ratification by the Russian Federation. Table 19 provides Kyoto Protocol targets and ratification details for APEC economies.

The Kyoto Protocol provides a number of flexibility mechanisms that allow countries to meet their targets at least cost. The three main mechanisms are international emissions trading, joint implementation and the clean development mechanism. Further details about these and other mechanisms as well as a complete copy of the Kyoto Protocol can be found at http://unfccc.int/resource/convkp.html.

At the fourth session of the Conference of the Parties (COP 4), held in Buenos Aires in November 1998, Parties adopted the so-called 'Buenos Aires Plan of Action'. This Plan of Action set out a programme of work covering both the 'unfinished business' of the Kyoto Protocol and ongoing implementation issues under the Convention, such as financial assistance and technology transfer. A deadline to complete the Plan of Action was set as COP 6.

In November 2000, at the sixth Conference of the Parties in the Hague, it was hoped that all outstanding rules and guidelines surrounding the Kyoto Protocol could be agreed on for its implementation. But despite extending the conference an additional 24 hours no agreement was met and the meeting was suspended until July 2001. The major impediments to an agreement included to what extent mechanisms could be used by countries to meet their targets, as well as the level of emissions that could be offset by carbon sinks.

However, before the resumption of COP 6 President George W. Bush wrote to key republican Senators Chuck Hagel, Jesse Helms, Larry Craig and Pat Roberts on 13 March, 2001, stating that he opposed the Kyoto Protocol because of its lack of developing country commitments and that it would increase costs for the US. He also announced that the US would undertake a fundamental high-level review of its climate change policy.

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82 The Secretariat of the United Nations Framework Convention on Climate Change. http://www.unfccc.int.

Table 19 APEC economies and the Kyoto Protocol

Party	Kyoto target Percentage of 1990 base	Date of signature	Date of ratification (R), approval (A) or acceptance (At)[1]
Australia	108	29/04/1998	
Brunei Darussalam	na		
Canada	94	29/04/1998	17/12/2002 (R)
Chile	na	17/06/1998	26/08/2002 (R)
China	na	29/05/1998	30/08/2002 (A)
Hong Kong, China	na		
Indonesia	na	13/07/1998	
Japan	94	28/04/1998	04/06/2002 (At)
Korea	na	25/09/1998	
Malaysia	na	12/03/1999	04/09/2002 (R)
Mexico	na	09/06/1998	07/09/2000 (R)
New Zealand	100	22/05/1998	19/12/2002 (R)
PNG	na	02/03/1999	28/03/2002 (R)
Peru	na	13/11/1998	12/09/2002 (R)
Philippines	na	15/04/1998	
Russia	100	11/03/1999	
Singapore	na		
Chinese Taipei	na		
Thailand	na	02/02/1999	28/08/2002 (R)
United States[2]	93	12/11/1998	
Viet Nam	na	03/12/1998	25/09/2002 (R)

Notes: 1: Status as of December 2002.
2: In March 2001 the United States rejected the Kyoto Protocol.

Source: The Secretariat of the United Nations Framework Convention on Climate Change. http://www.unfccc.int.

On 11 June, President Bush issued a statement on the findings of an interim report of the climate change policy review. He reiterated his view that the Kyoto Protocol is flawed, but accepted the scientific evidence on climate change. He indicated that the US would take a leadership role on addressing climate change, working with the United Nations framework for a global solution. Apart from announcing further initiatives to advance climate change science, the US has provided five principles which will guide its approach on addressing climate change:

- the adoption of a truly global solution, including all major emitters;
- the use of market based mechanisms;
- the need to encourage technological innovation;
- the adoption of a flexible approach that will assist technological advances; and
- continued economic growth for the US and the world.

In July 2001, COP 6 resumed in Bonn and continued to work towards consensus on key issues under the Buenos Aires Plan of Action despite the position adopted by the US. At the end of the resumed meeting ministers agreed to a text outlining rules for the implementation of the Kyoto Protocol covering major areas including:

- financial assistance for developing countries;
- technology transfer;
- flexibility mechanisms;
- adverse impacts of climate change and response measures on developing countries;
- land use, land-use change and forestry, including agreement on the list of eligible 'sink' activities allowed under the Protocol; and
- compliance.

However, due to insufficient time at that meeting, all outstanding issues were not finalised. At COP 7 at Marrakesh in October-November 2001 technical rules as well as outstanding issues relating to the Protocol's compliance regime, the level of activity allowed for sinks projects and the rules for the use of the Protocol's mechanisms, including international emissions trading, were to be decided.

COP 7 saw the finalisation of issues relating to the operational details of the Kyoto Protocol, opening the way for ratification by governments. A number of important rules for implementing the Protocol were agreed, but the issue of US and developing country commitments remained unresolved. In addition there remain a number of technical details to be agreed before flexibility mechanisms, compliance and reporting procedures can become operational.

In February 2002 President Bush announced a new approach to the challenge of global climate change. In the near term the US has committed itself to vigorously pursue emission reductions even in the absence of complete knowledge. This approach recognises that sustained economic growth is an essential part of the solution, not the problem. Economic growth will make possible the needed investment in research, development and deployment of advanced technologies that will provide the breakthroughs needed to dramatically reduce emissions in the long term.

The 'new approach' has a number of initiatives, of which the most important is the cutting of greenhouse gas intensity by 18 percent over the next 10 years. The goal is to reduce the rate of emissions from an estimated 183 metric tons per million dollars of GDP in 2002, to 151 metric tons per million dollars of GDP in 2012.

At COP 8 at New Delhi in October-November 2002, parties:[83]

- "Adopted the Delhi Ministerial Declaration on Climate Change and Sustainable Development.
- Adopted rules of procedure for the executive board of the Clean Development Mechanism (CDM).
- Completed work on the reporting required of developed countries to assess their compliance under the Kyoto Protocol.
- Adopted guidance to the Global Environment Facility (GEF) for managing two new funds established at COP-7 to assist developing countries.
- Adopted new guidelines for national communications to be submitted by developing countries reporting on their emissions and steps they are taking to meet their commitments under the Framework Convention.
- Requested the Intergovernmental Panel on Climate Change (IPCC) and the Montreal Protocol's Technological and Economic Assessment Panel to conduct a special report on the question of HFCs/PFCs - compounds that have replaced ozone-depleting substances but contribute to climate change."

83 Pew Center on Global Climate Change (2002).