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APEC Energy Security and Sustainable Development Through Efficiency and Diversity, Economic Issues in Technology R&D, Adoption and Transfer

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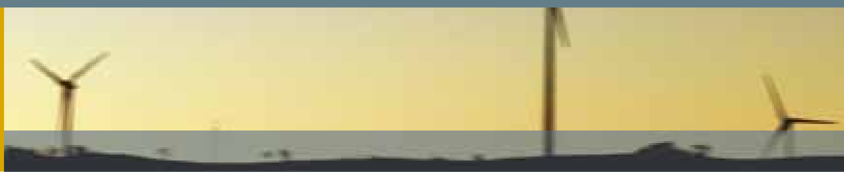
APEC energy security

and sustainable development through efficiency and diversity

economic issues in technology R&D, adoption and transfer



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foreword

The Asia Pacific Economic Cooperation forum – APEC – has an important role to play in strengthening regional economic cooperation and in addressing the regional energy security and sustainable energy development issues that have become more prominent in recent years.

Key objectives in this report are to present an overview of the challenges facing APEC economies in meeting the region's growing energy requirements, with a focus on the energy requirements of the APEC stationary energy sector, and to assess the role that cleaner fuels and energy technologies can play in achieving a more secure and sustainable energy sector in the APEC region. The report also examines barriers to investment and policy options that encourage the development and deployment of energy technologies that can enhance energy security and environmental sustainability in the APEC region.

The report has been prepared in anticipation of the eighth meeting of the APEC Energy Ministers Meeting to be held in Darwin, Australia on 27–30 May 2007. To support energy policy formulation by energy ministers, relevant background information is provided on clean and energy efficient technologies, alternative and renewable fuels, and environmentally sustainable energy technologies.

Phillip Glyde
Executive Director
May 2007

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summary

» Key objectives in this report are to present an overview of the challenges facing APEC (Asia Pacific Economic Cooperation) economies in meeting the region's growing energy requirements, with a focus on the energy requirements of the APEC stationary energy sector assess the role that cleaner fuels and energy technologies can play in achieving a more secure and sustainable energy sector in the APEC region. In the report, barriers that may exist to investment in the development and transfer of energy technologies are identified and examined. Policy options for the development and deployment of these technologies are also assessed.

» Through the Energy Security Initiative, the APEC forum has established a framework that enhances energy security in the region and the prospects for sustainable development. However, there continue to be major policy challenges in achieving adequate, reliable, affordable and cleaner energy in APEC economies. Two important aspects of a cooperative policy response to these challenges are to improve the operation of energy markets and to adopt more energy efficient and cleaner fuels and technologies.

» If energy markets are more efficient, their flexibility to adjust to temporary or sustained changes in energy supply and demand conditions is enhanced. A key area for consideration is facilitating energy trade and investment within the APEC region. This has the potential to significantly increase the efficiency of energy markets, providing both energy security and sustainable energy devel-

APEC – members

Founding members (1989)
Australia
Brunei Darussalam
Canada
Indonesia
Japan
Republic of Korea
Malaysia
New Zealand
Philippines
Singapore
Thailand
United States

First enlargement (1991)
People's Republic of China
Hong Kong, China
Chinese Taipei

Second enlargement (1993)
Mexico
Papua New Guinea

Third enlargement (1994)
Chile

Fourth enlargement (1998)
Peru
Russian Federation
Viet Nam

opment benefits to the APEC region. Liberalisation of trade and investment in the energy sector could also improve access to new and enhanced energy technologies.

- A major policy challenge for APEC economies is therefore to identify and address energy trade and investment barriers to the development and deployment of more energy efficient and cleaner fuels and technologies. The APEC forum can also enhance regional economic prospects through sharing information about energy policy analysis and experience, including information on energy efficiency.

APEC energy market developments

- The APEC region's share of the global economy is growing. In 2006, the region accounted for around 58 per cent of global output. Much of the growth in APEC's share in recent years has been driven by rapidly industrialising lower income APEC economies, in particular China. On a purchasing power parity basis, China accounted for around 16 per cent of world income in 2006. With significant foreign direct investment (FDI) and productivity growth likely to continue in China, its share of the world economy could increase significantly in coming decades. Comparatively stronger growth in developing Asia, China and the Russian Federation than in the rest of the world is likely to lead to further growth in the APEC region's share of the global economy in the future.
- The APEC region is also the world's major consumer of energy, with consumption currently dominated by the United States and China. In 2004, these two countries together accounted for 36 per cent of the region's energy consumption. Notably, China's strong economic performance has resulted in total primary energy consumption in China increasing at an average annual rate of around 11 per cent between 2001 and 2004. Continued strong economic growth is expected to drive demand for energy over the medium and longer term.
- Rapid growth in energy consumption, coupled with rising international energy prices and an increasing dependence on energy imports, has made energy security and sustainable development of the energy sector key issues for consideration by the APEC forum in recent years. For example, the gap between primary energy consumption and production in the region more than doubled between 1992 and 2004, with net imports of oil rising strongly. APEC economies are heavily dependent on oil suppliers outside the region, with only 21 per cent of oil imports sourced from other APEC economies. By

contrast, 89 per cent of coal imports and 79 per cent of natural gas imports are sourced from other APEC economies. As a consequence, there is strong interest in cooperation among APEC members in these areas.

long term energy challenges in the APEC region

- APEC's long term energy requirements will be substantial, particularly given projected strong growth in China. Based on ABARE projections, between 2004 and 2030, primary energy consumption in the APEC region is projected to increase by 67 per cent or, on average, by 2.0 per cent a year. Notably, the share of China in APEC primary energy consumption is projected to increase from 25 per cent in 2004 to 34 per cent in 2030. The share for other lower income economies is projected to remain around 21 per cent, while the share for higher income economies is projected to fall from 54 per cent in 2004 to 45 per cent in 2030.
- Energy consumption in APEC's stationary energy sector increased on average by 0.2 per cent a year over the period 1992–98, compared with an average of 2.2 per cent a year in the transport sector. In the lower income APEC economies, rapid industrialisation since 1998 has led to an acceleration of growth in stationary energy consumption – to an average rate of 2.4 per cent a year over the period 1998–2004.
- Over the long term, continued rapid growth in the industrial sectors of lower income APEC economies will support growth in stationary energy consumption. Electricity is a significant part of final stationary energy consumption in the APEC region (28 per cent in 2004), and the share of electricity in APEC's stationary energy sector has been increasing over time. Accordingly, much of the international effort to reduce energy consumption and to abate carbon dioxide emissions is focused on providing cleaner energy supply options for electricity generation and on improving energy efficiency in end use applications in the stationary energy sector.

energy security challenges

- From an energy security perspective, it is important to consider the long term energy challenges that relate to long term energy requirements and to temporary supply disruptions. Diversification of fuel sources and fuel types is one of the most important components of longer term policy responses to addressing energy security risks. Diversification of fuel sources can be achieved through:

- diversification of energy production – for example, by reducing the dependence of economies on higher risk sources of energy by diversifying the geographic location of fuel sources
- diversification of energy consumption – for example, by reducing the dependence of economies on higher risk forms of energy by diversifying fuel types in energy consumption.

» A further challenge for energy policy makers in the APEC region is the substantial investment in energy infrastructure that will be required to meet the projected growth in energy consumption in the region. Securing the finances for energy projects will pose challenges to energy industries throughout the region.

» Energy supply disruptions may occur in isolation or simultaneously, at any point in the energy supply chain, originate at a range of geographic locations, and can affect one or more fuel types. There are several features of energy markets that have the potential to increase the risk exposure of economies to temporary or sustained changes in relative energy prices – these include concentration in fuel types, fuel sources, energy infrastructure and transport networks.

sustainable development challenges

» It is important to recognise the tradeoffs between the costs of investing in energy efficiency and cleaner technologies and the benefits from reducing environmental damage over the longer term. Air pollution through the emission of various gases during energy production and consumption activities is the major form of environmental damage considered in this study. Air pollution may have local, regional or global impacts and includes emissions such as particulate matter, sulfur dioxide (SO_2), nitrous oxides (NO_x) and carbon dioxide (CO_2).

» There are significant challenges for APEC economies in assessing and implementing policy response measures to achieve long term energy goals without compromising sustainable development objectives. In general, energy security and environmental sustainability in individual economies and the APEC region may be enhanced by considering various options, such as facilitating investment in energy efficiency and cleaner technologies, including technology research and development (R&D), adoption and transfer; removal of market impediments, including trade and investment liberalisation and reducing or removing energy subsidies; adopting a diversified portfolio of interchangeable energy forms and energy supply sources; enhancing interconnection of energy systems; facilitating timely investment in energy production, transport and storage facilities; and through facilitating information sharing on energy matters.

- Several broad options that may be considered in reducing long term energy consumption and/or particulate and greenhouse gas emissions include removing distortions that encourage excessive energy consumption or limit access to alternative technologies, adopting more energy efficient technologies, fuel switching to less emissions intensive fuel options, and sequestering emissions by investing in technologies that capture emissions directly during the fuel combustion process.

technology options for APEC's stationary energy sector

- As noted earlier, growth in energy consumption in APEC's stationary energy sector is expected to remain strong. Cleaner energy supply options for electricity generation will remain an important priority for APEC economies. In addition, improving energy efficiency in end use applications also has an important role to play in slowing growth in stationary energy consumption in the APEC region. In particular, in lower income APEC economies, energy intensive industries are likely to be the primary focus of energy efficiency and conservation programs, as this sector makes up around 50 per cent of total final stationary energy consumption. In higher income APEC economies, the residential and commercial sectors are likely to remain the focus of energy efficiency and conservation measures.
- Many existing and new technology options for the stationary energy sector have the potential to make energy use in the APEC region more sustainable from an environmental perspective. The choice of technology options adopted in any economy will be affected by the cost of alternative technologies, resource availability and the price of competing fuels.

Box 1 at the end of the summary provides some information on energy efficiency and cleaner technologies available for deployment in the stationary energy sector.

barriers to investment in technology R&D, adoption and transfer

» Research and development activity, and the associated adoption and transfer of new and enhanced energy technologies, is a key mechanism to increase the efficiency, diversity and environmental sustainability of energy markets. The decision by industry to invest in a new or enhanced technology is influenced by a range of factors that affect their risk adjusted profitability assessment, including cost competitiveness, government policies and the level of perceived risk.

» A key barrier to investment in technology R&D, adoption and transfer is the limited economic incentives in energy markets to address energy security concerns or the negative impact of energy supply and use on human health and the environment. Also, the development of new technologies tends to be undertaken in a relatively small number of developed economies. The timing and pattern of technology transfer to other economies varies, but this process of technology diffusion is often gradual. Other important barriers to the diffusion of energy sector technologies that tend to impede or slow their adoption include concerns about intellectual property rights, macroeconomic conditions and trade restrictions, inadequate human capital, inadequate institutional capacities, and inadequate supporting infrastructure. Governments have an important role in encouraging technology R&D, adoption and transfer through addressing these issues.

policy options to encourage technology R&D, adoption and transfer

» Encouraging research and development and technology adoption and transfer are important building blocks for developing options for reducing growth in long term energy consumption and emissions.

encouraging R&D

» Policy options available to encourage R&D activity include providing greater economic incentives for industry investment in R&D (to reduce the costs and/or risks of the activity) and directly supporting public investment in R&D (including public–private partnership arrangements). Other options are strengthening property rights to reduce the risks associated with private investment in R&D, since private investors would be more likely to obtain an adequate return from any discoveries, and providing government support for R&D through grants, subsidies and tax incentives. Also, providing support for R&D joint ventures and international collaboration between private companies and/or public research organisations in one or more economies can encourage R&D activity by reducing the costs and risks of R&D projects by facilitating information sharing.

encouraging technology adoption and transfer

- There are several policy options that encourage technology adoption and transfer by providing greater economic incentives for industry investment in new and enhanced technologies. International cooperation, such as collaborative partnership arrangements, is an important component of any policy response.
- Policy options include setting government technology and performance standards; providing government support for technology adoption through grants, subsidies and tax incentives; establishing emissions trading schemes; applying an emissions tax; or establishing joint ventures and international collaboration between private companies in one or more economies to reduce the costs and risks of these investment projects by facilitating information sharing. Technology transfer may also be encouraged by strengthening intellectual property rights and providing institutional support and training in developing economies.
- In addition to APEC initiatives, many APEC economies are active participants in energy policy cooperation initiatives undertaken by the International Energy Agency (IEA), the Association of South East Asian Nations (ASEAN), the Asia Pacific Partnership on Clean Development and Climate (AP6), the East Asia Summit (EAS), the Group of Eight (G8), and the Meeting of G20 Finance Ministers and Central Bank Governors.
- International cooperation can assist in the development and deployment of new energy technologies in the APEC region. For example, in Fisher et al. (2006), cooperation within the framework of the AP6 in technology adoption and transfer is shown to potentially reduce electricity consumption in the partnership region over the period 2010–50 to about 7 per cent below reference case levels, hence reducing the overall demand for energy and electricity supply infrastructure requirements over this period. The study also shows that global greenhouse gas emissions could be reduced by up to 17 per cent in 2050 compared with reference case levels if partnership economies introduce carbon capture and storage technologies for electricity generation for coal and gas fired electricity generation.

box 1 **energy efficiency and cleaner technologies in the stationary energy sector**

technology options in electricity generation

coal fired power plants

Pulverised coal systems with a subcritical boiler are currently the most widespread coal fired technology, accounting for more than 90 per cent of world coal fired electricity generation capacity. Improving these technologies by incorporating a supercritical boiler is significantly increasing the thermal efficiency of these systems (to around 45 per cent, compared with an average of around 36 per cent for subcritical units).

Supercritical power generation units are now the standard for new power generation plants in most developed regions. Ultra supercritical units, which can operate at efficiencies of up to 55 per cent (LHV), are being developed in Europe, the United States and Japan.

Other technologies at less advanced stages of development include fluidised bed conversion, integrated gasification combined cycle (IGCC), lignite drying and ultra clean coal. Both lignite drying and ultra clean coal are technologies that focus on improving the quality of the fuel rather than the combustion process.

Current and potential future emission reductions can be achieved through the application of power generation plant design features and downstream cleanup processes. For example, sulfur dioxide and particulate emissions can be controlled by downstream cleanup processes, such as flue gas desulfurisation (FGD). While not yet commercially proven, advanced technologies such as carbon capture and storage are being developed to provide reductions in carbon dioxide emissions beyond what is achievable through increases in thermal efficiency.

gas fired power plants

Natural gas combined cycle (NGCC) technologies are steadily replacing simple cycle gas turbine technologies for electricity generation. NGCC power generation plants are an established technology that now account for more than 50 per cent of the worldwide market for new electricity generating capacity. NGCC power generation plants have world's best practice thermal efficiencies of around 60 per cent using the latest turbine design. Improvements in gas turbine design are expected box 1 **energy efficiency and cleaner technologies in the stationary energy sector**

to raise this efficiency even further over time. NGCC power generation plants have the lowest carbon dioxide emissions of all fossil fuel based generation technologies because of the low carbon content of natural gas and the high efficiency of the power generation plants.

nuclear power

Many nuclear reactors that have been built since the early 1990s or are planned or under construction are advanced pressurised water reactors and advanced boiling water reactors, so-called 'generation 3' reactors. Generation 3 reactors incorporate passive safety measures that automatically activate in the event of a malfunction and have better burn up characteristics, making them more efficient in fuel use and producing less waste. Generation 4 reactor designs are currently being developed with a view for deployment by around 2030. The main feature of generation 4 reactors is that they substantially reduce the nuclear waste stream through their ability to use most of the input fuel and are more economic to operate.

renewable energy

The cost competitiveness of new renewable energy technologies is dependent on its regional context and the type of technology being considered. In rural areas, where grid based electricity supply is not available, new renewable energy technologies can offer a viable and safe alternative to traditional biomass fuels. In addition, hydroelectric or geothermal energy may be cost competitive to alternative energy technologies in areas with a strong hydroelectric or geothermal potential.

In well established energy markets, new renewable energy technologies are high cost energy options when compared with conventional energy sources, including coal, oil, gas, nuclear and hydroelectricity. The dependence of new renewable energy technologies on variable natural elements such as wind speed and solar radiation to achieve reliable production levels significantly increases energy production costs. Without further significant technological development to reduce costs, these technologies are unable to provide a cost effective alternative to conventional energy sources for baseload power generation.

box 1 energy efficiency and cleaner technologies in the stationary energy sector

technology options in end use applications in the stationary energy sector

industry sector

The key industries with the greatest potential for reduced energy consumption through energy efficiency improvements include:

- iron and steel – the major fuel in the integrated iron and steel making process is metallurgical coal, which is used in blast furnaces to produce iron. Blast furnace production is expected to continue to be the dominant production process within the region in the medium term. The increasing use of electric arc furnaces for steel production has been beneficial from an energy efficiency and conservation perspective, but it is not typically suited to large scale applications. There are a number of studies that have identified best practice opportunities and have quantified the magnitude of the R&D that is needed for the development of new technologies in the industry.
- aluminium – the global aluminium industry is adjusting production processes in response to increased input costs, environmental performance requirements and market pressures. Opportunities include the use of inert cathodes and anodes in the short run, and in the longer run redesigning the electrolysis process to use aluminium chloride or carbothermic processes.
- cement – the greatest opportunity for energy savings in APEC cement production is in the wider adoption of large scale rotary dry kiln technologies in developing APEC economies, which are around 30 per cent more energy efficient than wet kiln processes. To reduce carbon dioxide emissions in the cement industry, technologies can be improved to allow for using waste heat for electricity generation; co-processing using alternative fuels; dry processing technologies through preheater installation and using more energy efficient grinding technologies.
- petroleum refining and chemicals – there are a number of new process technologies that could be used by the petroleum refining industry to reduce operating costs, improve energy efficiency and limit capital outlays. For example, upgrading processes to minimise vacuum distillation and thermal cracking, not only improves energy efficiency but also leads directly to the production of (more valuable) lighter sweeter products. Separation in the chemicals industry is a very energy intensive process, accounting for approximately 40 per cent of all energy used in the industry. Chemical separation could be achieved through the

box 1 energy efficiency and cleaner technologies in the stationary energy sector

use of membranes – energy savings would vary depending on application but could amount to between 20 and 60 per cent. The adoption of membrane based separation processes will require further research to be cost competitive with conventional separation processes.

residential and commercial sectors

There are a number of initiatives that can improve the energy efficiency of buildings and appliances. Increasing the energy efficiency of buildings may be achieved by upgrading energy efficiency features of existing buildings and showcasing environmental best practice in new buildings. Efficiency gains in appliances may be delivered through advanced technology, efficiency standards and labelling, increasing consumer awareness and reducing appliance standby power. Examples of technology options include:

- lighting – new developments in solid state lighting and light emitting diodes (LEDs) are expected to continue. If price and performance targets for solid state lighting are achieved over the next two decades, an estimated 30 per cent will removed from lighting energy consumption in 2025.
- intelligent systems – developments in intelligent systems for houses seem likely to provide the capacity to manage energy use of equipment, identify faults, and educate users. Flexible systems that have the potential to reduce energy consumption can be retrofitted to houses and equipment.
- heating and cooling – combined heating and cooling contributes to a significant share of global household energy demand, with the share ranging between 40 and 60 per cent of total residential energy use in developed economies. In most developed economies the majority of heating requirements are currently provided through natural gas or electric resistance furnaces and boilers. Energy requirements for air conditioning will be contained by improving building thermal performance and cooling technology efficiency.
- other examples – emerging television technologies, such as organic light emitting diodes, are expected to offer large screen TVs that use about as much energy as today's 34 cm portable TVs. Improved design combined with small solar cells and batteries have the potential to virtually eliminate stand-by energy use. The efficiency of computers can be improved through the use of laptops that currently consume less than 20 watts, compared with conventional computers that use over 100 watts.

1

introduction

The Asia Pacific Economic Cooperation forum comprises 21 member economies and is a major international organisation that has an important role in strengthening economic cooperation in the region. In 2006, APEC is estimated to have accounted for around 58 per cent of world output (IMF 2006). APEC energy production satisfied around 90 per cent of the region's energy requirements in 2004, but APEC energy self sufficiency varies widely between the major energy commodities – 104 per cent for coal, 67 per cent for oil and 109 per cent for gas (IEA 2006d). Importantly, from both an energy security and environmental sustainability perspective, the long term energy requirements of the APEC region will be substantial, particularly given projected strong growth in China.

Energy security and sustainable development have become key issues for the APEC forum in recent years. At the seventh meeting of APEC Energy Ministers (EMM7), held in the Republic of Korea in October 2005, Ministers reaffirmed their 'belief that access to adequate, reliable, affordable and cleaner energy is fundamental to the region's economic, social and environmental wellbeing'. At EMM7, ministers also 'encouraged APEC economies to accelerate cooperation to develop and deploy technologies that allow for more efficient energy use and energy diversification, furthering the region's energy security and sustainable development' (see box 2).

box 2 **securing APEC's energy future: responding to today's challenges for energy supply and demand**

extract from the APEC Energy Ministers' Declaration in October 2005

The seventh meeting of APEC Energy Ministers was held on 19 October 2005 in Gyeongju, the Republic of Korea. The following is an extract from the APEC Energy Ministers' Declaration (APEC 2005, pp. 1–2).

message from APEC Energy Ministers

1 We, Energy Ministers of the APEC economies, gathered for the 7th time in Gyeongju, Republic of Korea, on 19 October 2005 under the theme '*Securing APEC's Energy Future: Responding to Today's Challenges for Energy Supply and Demand*'.

box 2 **securing APEC's energy future: responding to today's challenges for energy supply and demand** *continued*

2 We met for the second consecutive year within the context of growing concerns about the impact of rising oil prices on APEC economies while significant demand growth and supply constraints continue. In doing so, we considered ways to respond to high oil prices and oil dependency, as well as the region's broader energy supply and demand challenges.

3 We shared our views that those energy challenges are serious concerns for our sustainable economic development and should be responded to urgently. We agreed that effective responses to high and increasingly volatile oil prices require a broad range of supply and demand-side measures, for example, strategic oil stocks for supply disruption response, facilitation of investment in oil exploration, production and refining, and measures to promote energy efficiency and diversification, including vehicle fuel efficiency and alternative transport fuels.

4 We expressed our condolences to the APEC economies affected by the Indian Ocean Tsunami and Hurricanes Katrina and Rita, noting the significant human and economic costs of these natural disasters and highlighting the need for regional cooperation on energy security and emergency preparedness.

5 We welcomed the address by the Acting Secretary General of the Organization of Petroleum Exporting Countries (OPEC) and directed the Energy Working Group (EWG) to more closely collaborate with OPEC, other producers, the International Energy Agency and other international energy organisations as part of efforts to improve the transparency of energy markets and reduce price volatility.

6 We reaffirmed our belief that access to adequate, reliable, affordable and cleaner energy is fundamental to the region's economic, social and environmental wellbeing and noted that energy efficiency and conservation measures will be vital to these efforts. Recognising the significant and evolving nature of the region's energy demand and supply challenges, and the need to acknowledge the individual circumstances of each APEC economy, we agreed that our cooperative efforts must continue to be substantial, flexible, sustainable and responsive.

7 We acknowledged the contribution of the EWG since our last meeting and directed it to continue its broad-based approach developed under the APEC Energy Security Initiative (ESI) and the CAIRNS Initiative and APEC Action Plan to Enhance Energy Security that enhance and expand the ESI.

8 We encouraged APEC economies to adopt best practice principles developed to facilitate cross-border energy trade, energy investment and energy emergency preparedness, and to share information and experiences on the implementation of these principles. We also encouraged APEC economies to accelerate cooperation to develop and deploy technologies that allow for more efficient energy use and energy diversification, furthering the region's energy security and sustainable development.

The 14th APEC Economic Leaders' Meeting was held in Ha Noi, Viet Nam on 18–19 November 2006 under the theme 'Towards a Dynamic Community for Sustainable Development and Prosperity'. In the Ha Noi Declaration, the economic leaders noted the challenges of meeting rapidly growing energy demands while minimising environmental effects. They instructed energy ministers to report in 2007 on ways in which APEC might further contribute to responding to these challenges through pursuing policies and technologies that promote the development of cleaner energy and the improvement of energy efficiency. Through this, the economic leaders aimed to enable economies to meet increasing energy needs with a lower environmental impact and to address climate change objectives (APEC 2006). The APEC Economic Leaders' Meetings (AELM) and Energy Ministers' Meetings (EMM) provide policy guidance and direction for the work of the Energy Working Group (EWG).

In recent years, the Asia Pacific Energy Research Centre (APERC) has released a number of major studies that have examined relevant issues addressing APEC energy security issues (see, for example, APERC 2000a, 2002, 2003b). In its latest outlook assessment, APERC (2006) examines a range of issues likely to influence future developments in APEC energy demand and supply.

ABARE has undertaken several market and policy assessments of the APEC region. Some key examples in this line of research are studies on APEC trade and investment liberalisation (see Schneider et al. 2000; Fairhead et al. 2002), new energy technologies in the APEC electricity and iron and steel sectors (Heaney et al. 2005), APEC energy security and temporary energy supply disruptions (Hogan et al. 2005), and sustained higher oil prices and new technologies in the APEC transport sector (McDonald et al. 2005).

The eighth meeting of the APEC Energy Ministers (EMM8) is to be held in Darwin, Australia on 27–30 May 2007. This study aims to provide relevant background information and economic analysis that may be used at EMM8 to support the development of new policies to accelerate the removal of barriers to the investment in clean and energy efficiency technologies, alternative and renewable fuels, and environmentally sustainable energy technologies such as carbon capture and storage (CCS).

Four key aspects to be addressed in this report are:

» What are the challenges that affect the ability of APEC economies to meet the region's growing energy needs in a secure, sustainable and equitable manner?

- What role can appropriate energy efficiency and emerging technologies, including advanced power generation technologies, play in meeting these challenges, with a focus on the stationary energy sector?
- What are the barriers to investment in the development and deployment of such technologies?
- How can investment in such technologies most effectively be encouraged?

In chapter 2, recent developments in APEC energy consumption, production and trade are outlined. Long term energy challenges are presented in chapter 3. Background information on the energy policy setting in the APEC region is presented in chapter 4. In chapters 5 and 6, information is presented on current and emerging energy efficiency and cleaner technologies for the supply side and demand side, respectively, of the APEC stationary energy sector – in these chapters, some emphasis is placed on recent developments and appropriate energy technologies in higher income and lower income economies. Barriers to investment in the development and deployment of energy technologies that address these challenges are discussed in chapter 7. The economic rationale for government intervention in encouraging technology R&D, adoption and transfer and appropriate policy response options are examined in chapter 8. Some key policy implications for the APEC forum are provided in chapter 9.

2

recent energy market developments in the APEC region

There is considerable diversity in the energy markets of the 21 economies that currently comprise APEC, reflecting, to a large extent, variations in economic size and structure, income levels and proximity to energy resources. In this chapter, background information is provided on APEC member economies and energy market developments, with some focus on the stationary energy sector.

An historical perspective of APEC energy consumption, production and trade since the 1970s is presented along with the structure of the energy market in 2004, the latest year for which comprehensive IEA energy data are available. It should be noted that energy data for the Russian Federation is available only since 1992, which limits historical comparisons – all figures include the break in the IEA energy time series. More detailed information for individual APEC economies on energy consumption and self sufficiency in 2004 is provided in appendix A.

APEC member economies and income levels

In 2006, APEC is estimated to have accounted for around 58 per cent of world output. Estimated output per person ranged from around US$43 200 in the United States to US$2460 in Papua New Guinea (table 1). It should be noted that output is given by gross domestic product based on purchasing power parity, which may vary from output estimates based on nominal exchange rates (this is particularly the case for China).

In this report, APEC economies are divided into two income groups based on output per person:

» **higher income group** – ten economies, which together accounted for 32 per cent of world output in 2006 – the largest two economies in this income category are the United States (20 per cent of world output) and Japan (6 per cent)

» **lower income group** – eleven economies, which together accounted for 25 per cent of world output in 2006 – the largest two economies in this income category are China (16 per cent) and the Russian Federation (3 per cent).

table 1 **key economic and energy consumption indicators for APEC member economies and membership in selected other forums, 2006**

APEC economy, by income category	gross domestic product per person a	gross domestic product a		total primary energy consumption b		IEA, ASEAN, AP6, EAS, G8 members
		level	world share	level	world share	
	US$	US$b	%	Mtoe	%	
higher income						
1 United States	43 236	12 939	19.8	2325	21.0	IEA, AP6, G8
2 Canada	35 779	1164	1.8	270	2.4	IEA, G8
3 Hong Kong, China	35 396	249	0.4	17	0.1	–
4 Australia	32 127	663	1.0	116	1.0	IEA, AP6, EAS
5 Japan	31 866	4 069	6.2	533	4.8	IEA, AP6, EAS, G8
6 Singapore	29 743	132	0.2	26	0.2	ASEAN, EAS
7 Chinese Taipei	29 244	672	1.0	104	0.9	–
8 New Zealand	25 655	106	0.2	18	0.2	IEA, EAS
9 Brunei Darussalam	25 511	10	0.01	3	0.02	ASEAN, EAS
10 Korea, Rep. of	21 877	1 065	1.6	213	1.9	IEA, AP6, EAS
total	37 401	21 070	32.3	3624	32.8	
lower income						
11 Chile	12 737	209	0.3	28	0.3	–
12 Malaysia	11 915	315	0.5	57	0.5	ASEAN, EAS
13 Russian Federation	11 904	1 692	2.6	642	5.8	G8
14 Mexico	10 604	1133	1.7	166	1.5	–
15 Thailand	8 877	584	0.9	97	0.9	ASEAN, EAS
16 China, People's Rep. of	8 004	10 518	16.1	1610	14.6	AP6, EAS
17 Peru	6 289	178	0.3	13	0.1	–
18 Philippines	5 160	443	0.7	44	0.4	ASEAN, EAS
19 Indonesia	4 753	1 055	1.6	174	1.6	ASEAN, EAS
20 Viet Nam	3 255	275	0.4	50	0.5	ASEAN, EAS
21 Papua New Guinea	2 460	15	0.02	2	0.0	–
total	9 250	16 417	25.2	2882	26.1	
APEC	11 750	37 487	57.5	6506	58.8	
world	10 213	65 245	100.0	11059	100.0	

a Gross domestic product based on purchasing power parity (PPP); APEC economies are ranked according to GDP per person in 2006. **b** Total primary energy consumption (TPEC) is also referred to as total primary energy supply (TPES); energy data are for 2004.
Sources: IMF (2006); IEA (2006).

Other international organisations that are important from a regional energy security and environmental sustainability perspective include the International Energy Agency (IEA), the Association of South East Asian Nations (ASEAN), the Asia Pacific Partnership on Clean Development and Climate (AP6; also referred to as APPCDC), the East Asia Summit (EAS) and the OECD's group of eight (G8). Fifteen APEC member economies are members of at least one of these other international organisations (see table 1).

The APEC region includes seven IEA members (from a total IEA membership of 26 economies), seven ASEAN members (total membership of ten), five AP6 members (total membership of six that also includes India), twelve EAS members (total membership of sixteen) and four G8 members (total membership of eight).

coverage of the stationary energy sector

The major focus in this report is to examine the role of energy technologies in achieving more secure and environmentally sustainable systems of energy supply in the APEC stationary energy sector. The stationary energy sector includes electricity generation and the direct combustion of fuels for purposes other than transport (AGO 2006). These direct combustion activities include:

» nonelectricity industries – such as petroleum refining and the manufacture of solid fuels.

» manufacturing and construction industries – including metals; chemicals; pulp, paper and print; nonmetallic minerals; and food and beverages.

» small combustion – such as home heating, onsite diesel generation, and on-farm machinery.

In 2004, the stationary energy sector and the transport sector accounted for 62 per cent and 28 per cent, respectively, of total final energy consumption in the APEC region. The remaining 10 per cent of APEC final energy consumption was accounted for in nonenergy uses of energy resources such as consumption of lubricants and greases, bitumen and solvents (see table 10 in appendix A).

energy consumption in the APEC region

It is important to distinguish between three different stages of energy consumption:

- primary energy consumption – the use of energy that is mainly in the form of primary fuels and is sourced from domestic production of primary fuels, net imports and stock drawdown (referred to as primary energy supply by the IEA).
- energy conversion activities – these involve the conversion or transformation of primary fuels to secondary or derived fuels and include, most importantly, electricity generation and petroleum refining.
- final energy consumption – the energy consumed in end use applications and is equal to the net amount of fuel available for final consumption (that is, primary energy consumption less net losses resulting from conversion processes).

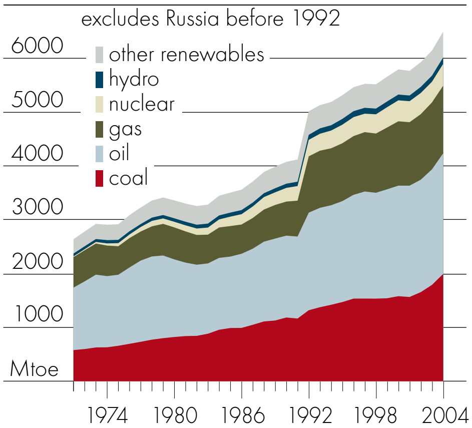
Electricity generation is an important part of the stationary energy sector and is the main energy conversion activity considered in this report.

primary energy consumption

Primary fuels are forms of energy obtained directly from nature and include both nonrenewable and renewable resources:

- nonrenewable resources – these include fossil fuel energy resources, such as coal, crude oil, natural gas liquids and natural gas. There is a finite but unknown stock of nonrenewable energy resources and exploration activity is required to identify economic reservoirs or deposits. Proved reserves, or economic demonstrated resources (EDR), are estimates of resources that can be recovered in the future with reasonable certainty.
- renewable resources – these include, for example, hydro, geothermal, solar and wind energy, and combustible renewables and waste. The key feature of renewable resources is that production in one period does not necessarily affect production in subsequent periods; it may be noted that some renewable resources are exhaustible, whereby it is possible to deplete the resource (for example, geothermal energy may be sustained in a given location provided the rate of depletion does not exceed heat replenishment).

In 2004 the APEC region accounted for 59 per cent of total primary energy consumption in the world economy (see table 1). Higher income APEC economies accounted for 33 per cent of world primary energy consumption, with shares of fig A **APEC total primary energy consumption, by fuel type**



21 per cent for the United States and 5 per cent for Japan. The corresponding share for lower income APEC economies was 26 per cent, with shares of 15 per cent for China and 6 per cent for the Russian Federation.

A long term historical perspective of total primary energy consumption in the APEC region is presented in figure A. Between 1992 and 2004, APEC primary energy consumption increased on average by 2.2 per cent a year, compared with 2.3 per cent between 1971 and 1991. Changes in the growth path of APEC energy consumption over the past decade have been striking, with the slowdown following the Asian economic downturn in 1997 and the strong upturn in recent years, with growth rates of 3.6 per cent in 2003 and 5.7 per cent in 2004.

One of the most important features of the world economy in recent years has been the strong economic performance of China. Total primary energy consumption in China increased at an average annual rate of around 11.2 per cent between 2001 and 2004 (IEA 2006d). Energy consumption growth has also been relatively strong in ASEAN economies in recent years.

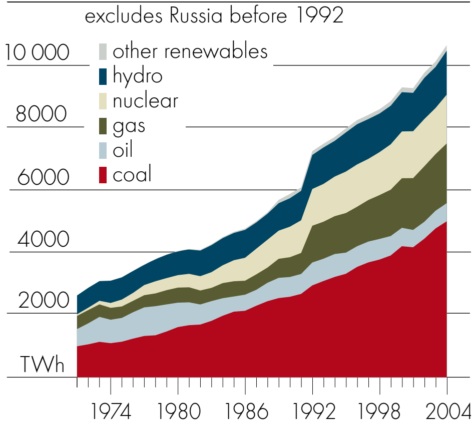
In 2004, total primary energy consumption in the APEC region was sourced from oil (35 per cent), coal (31 per cent), gas (19 per cent), combustible renewables and waste (7 per cent), nuclear (6 per cent), hydro (2 per cent) and other renewable energy (less than 1 per cent) – see table 7 in appendix A for the corresponding fuel shares in individual APEC economies. Since the 1970s, the fuel mix in primary energy consumption has become slightly more diversified.

electricity generation

Electricity is an important source of energy in end use applications, and is produced from a range of primary fuels. APEC electricity output increased on average by 3.3 per cent a year between 1992 and 2004, compared with 4.3 per cent a year between 1971 and 1991 (figure B).

In 2004, electricity generation in the APEC region was sourced from coal (47 per cent), gas (18 per cent), nuclear (15 per cent), hydro (13 per cent), oil (5 per cent) and other renewable energy (2 per cent) – see table 8 in appendix A for the corresponding fuel shares in individual APEC economies. Between 1992 and 2004, the fuel shares increased for coal (from 41 per cent in 1992) and gas (16 per cent), remained unchanged for other renewables and fell for other fuels (in particular, the oil share halved from 10 per cent in 1992).

fig B **APEC electricity generation, by fuel type**



Notably, China is highly dependent on coal for electricity generation. In 2004, 78 per cent of electricity generation in China was sourced from coal, the second highest coal share for any APEC economy (see table 8 in appendix A). The highest coal share in electricity generation was 79 per cent in Australia. The coal share for the United States, the largest APEC economy, was 50 per cent in 2004.

final energy consumption

fuel use in final energy consumption – stationary energy sector and transport

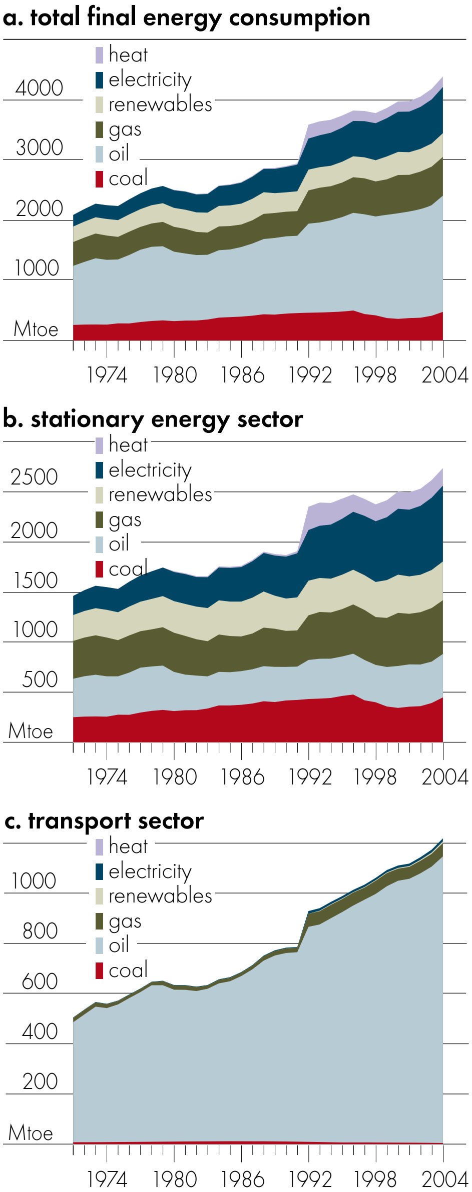
APEC final energy consumption increased at an average rate of 1.7 per cent a year between 1992 and 2004 (also 1.7 per cent between 1971 and 1991) (figure C panel a).

In 2004, total final energy consumption in the APEC region was sourced from oil (44 per cent), electricity (18 per cent), gas (15 per cent), coal (11 per cent), renewable energy (9 per cent, mainly combustible renewables and waste) and heat (4 per cent) – see table 9 in appendix A for the corresponding fuel shares in individual APEC economies.

There are major differences in the pattern of fuel use in the stationary energy sector (panel b) and the transport sector (panel c). (Note that nonenergy use accounts for around 10 per cent of total final energy consumption in the APEC region but is not illustrated separately in figure C.)

fig C **APEC final energy consumption, by fuel type**

all sectors, the stationary energy sector and transport; excludes Russia before 1992



In the APEC stationary energy sector, final energy consumption increased at an average rate of 1.3 per cent a year between 1992 and 2004 (also 1.3 per cent between 1971 and 1991). Notably, electricity use in the sector increased at an average growth rate of 3.4 per cent a year between 1992 and 2004, well above the rates for other fuel types.

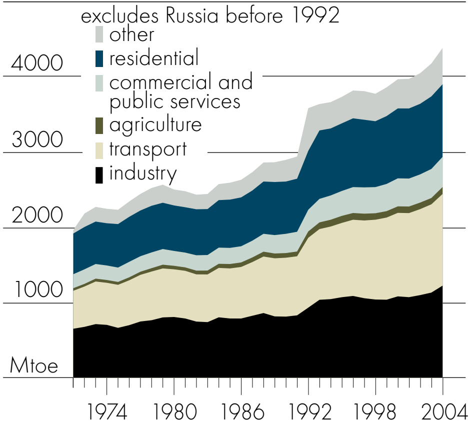
Overall, fuel use in the APEC stationary energy sector is highly diversified and is more diversified than the fuel mix in either total primary energy consumption or electricity generation. In 2004, final energy consumption in the APEC stationary energy sector was sourced from electricity (28 per cent), gas (20 per cent), coal (16 per cent), oil (16 per cent), renewable energy (14 per cent) and heat (6 per cent).

By contrast, the APEC transport sector is highly dependent on oil (94 per cent share in 2004). Final energy consumption in the APEC transport sector increased at an average rate of 2.3 per cent a year between 1992 and 2004 (similar to the growth rate of 2.2 per cent between 1971 and 1991).

energy consumption in end use activities – decomposition of the stationary energy sector

A long term perspective of energy consumed in the main end use activities in the APEC region is presented in figure D. In 2004, total final energy consumption in the APEC region was undertaken in industry (28 per cent), transport (28 per cent), the residential sector (22 per cent), commercial and public services (9 per cent), agriculture (2 per cent), non-specified other energy use (1 per cent) and nonenergy use (10 per cent) – see table 10 in appendix A for the corresponding sector shares in individual APEC economies.

fig D **APEC total final energy consumption, by end use activity**



Energy consumption, by fuel type, in each of the four identified end use activities in the stationary energy sector since the 1970s is presented in figure E (see also tables 11–14 in appendix A):

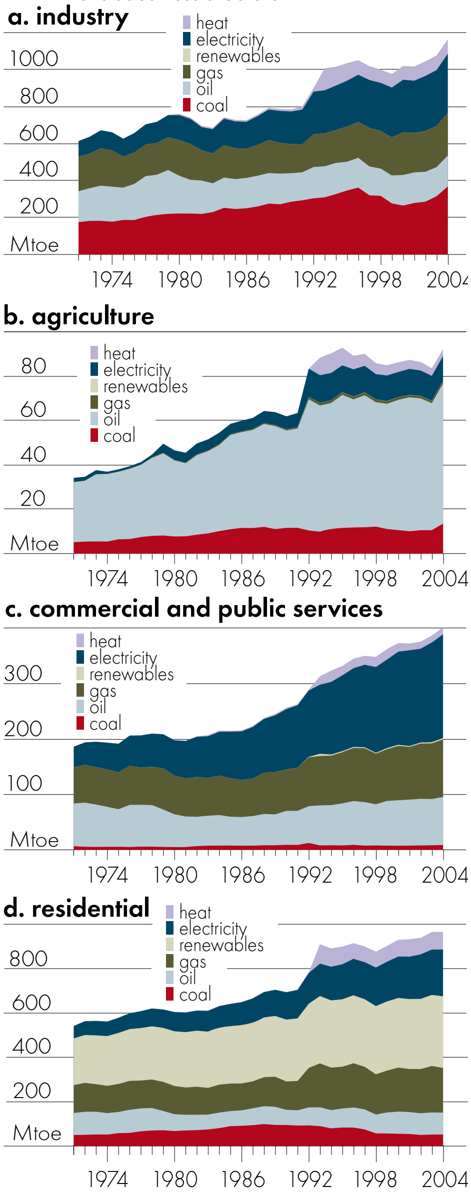
» industry (panel a) – final energy consumption in this sector grew on average by 2.2 per cent a year between 1992 and 2004. The main fuel shares in 2004 were for coal (30 per cent), electricity (26 per cent), gas (19 per cent) and oil (14 per cent).

» agriculture (panel b) – final energy consumption in this sector grew on average by 0.8 per cent a year between 1992 and 2004. The largest fuel shares in 2004 were for oil (68 per cent; 90 per cent share in higher income economies), coal (15 per cent) and electricity (12 per cent).

» commercial and public services sector (panel c) – final energy consumption in this sector grew on average by 2.8 per cent a year between 1992 and 2004. The largest fuel shares in 2004 were for electricity (47 per cent), gas (26 per cent) and oil (22 per cent).

» residential (panel d) – final energy consumption in this sector grew on average by 1.8 per cent a year between 1992 and 2004. The largest fuel shares in 2004 were for renewable energy (33 per cent; mainly combustible renewables and waste in lower income economies), electricity (22 per cent) and gas (21 per cent).

fig E **final energy consumption in end use activities in the APEC stationary energy sector, by fuel type**
excludes Russia before 1992



Electricity has recently been the strongest growing energy source in all end use activities of the stationary energy sector, with the exception of agriculture. Between 1992 and 2004, the average annual growth rate for electricity use was 2.8 per cent for industry, 3.8 per cent for commercial and public services, and 3.6 per cent for residential.

It should be noted that, because of concerns over data reliability, combustible renewables and waste are often excluded from international energy market assessments where the focus is on economic issues relating to industry and international trade. Combustible renewables and waste are included in this report to highlight the diversity in the energy mix across APEC economies and, in particular, the importance of this energy source for residential use in several low income economies. Combustible renewables and waste are also a significant source of air pollution in these economies, which is an important issue for the environmental sustainability of the APEC region.

APEC energy production, trade and prices

energy production and trade

From an energy security perspective, it is useful to distinguish between domestic sources of energy that are within the policy jurisdiction of national governments in the APEC region and imported sources of energy.

APEC energy production increased on average by 1.7 per cent a year between 1992 and 2004 (compared with 2.4 per cent between 1971 and 1991). In 2004, energy production in the APEC region was sourced from coal (35 per cent), oil (25 per cent), gas (23 per cent), renewable energy (10 per cent, including hydro with 2 per cent) and nuclear (7 per cent), as shown in figure F.

In the APEC region, the gap between primary energy consumption and production more than doubled between 1992 and 2004, mainly as a result of rising net imports of oil (figure G). In 2004, the APEC region recorded net exports of 109 Mtoe (million tonnes of oil equivalent) for gas and 70 Mtoe for coal, and net imports of 747 Mtoe for oil (crude oil, natural gas liquids and feedstocks) and 3 Mtoe for petroleum products.

APEC economies draw only 21 per cent of their imported oil from other APEC economies and are heavily dependent on oil suppliers outside the region (see

fig F **APEC energy production and net energy imports**
excludes Russia before 1992; net imports includes stock drawdown

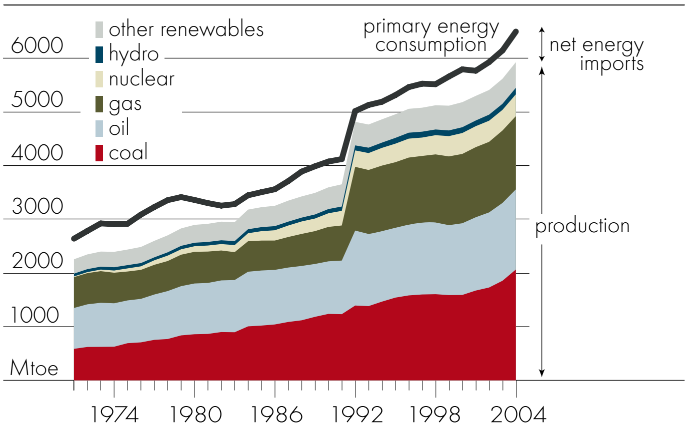
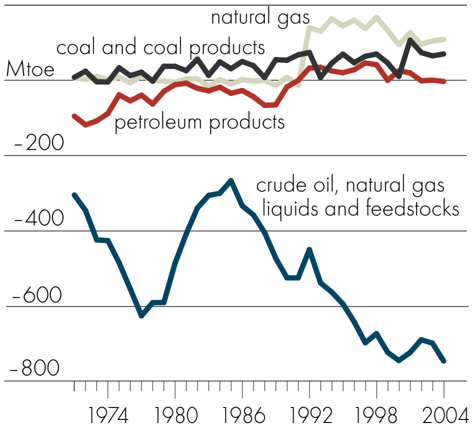


fig G **APEC net energy trade, by fuel type**
excludes Russia before 1992



appendix B). By contrast, 89 per cent of their internationally supplied coal and 79 per cent of international natural gas supplies come from other APEC members. As a consequence, there are strong interests in cooperation among APEC members in these areas.

Energy self sufficiency, calculated as energy production divided by primary energy consumption and presented in percentage terms, provides an indication of the extent to which each APEC economy is able to meet domestic primary energy requirements from domestic sources. Overall, APEC economies produced around 90 per cent of the region's energy needs in 2004, with APEC production accounting for 104 per cent of coal consumption and 109 per cent of gas consumption, but only 67 per cent of oil consumption – see table 15 in appendix A for energy self sufficiency levels in individual APEC economies.

world energy prices

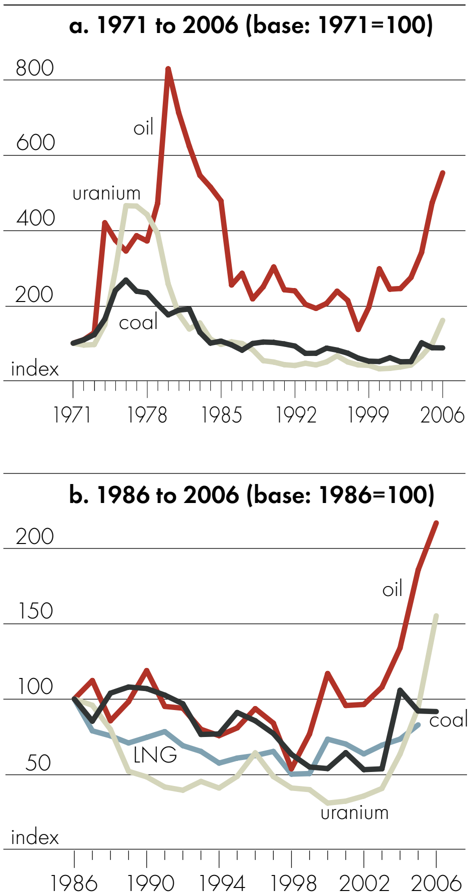
Developments in world energy prices, which are determined by demand and supply conditions in the world economy, have important economic implications for the APEC region. Indexes of real world prices for major energy commodities including oil, LNG, coal and uranium are presented in figure H.

Major fluctuations in world energy prices have been observed in the oil market, particularly through supply side shocks in the 1970s. World oil prices increased sharply during the two oil shocks in the 1970s and, following a period of lower prices after 1986, have increased again in recent years (panel a). Unlike the earlier oil shocks that were caused by changed OPEC oil production policies, the recent increase has mainly been caused by increased demand for oil, particularly in China. World oil prices continued to be volatile during 2006 in response to geopolitical issues, a reduction in spare production capacity and some supply side influences (see McDonald et al. 2005; Penm et al. 2006).

The supply side oil shocks in the 1970s had a lagged impact on the prices of other energy commodities. The expectation of a sustained increase in oil prices provides economic incentives for oil users to assess alternative energy options, resulting in fuel switching and increased demand for alternative energy sources to the extent that substitution possibilities exist. Prices of both coal and uranium increased sharply in the mid-1970s (panel a).

World oil prices fell steadily during the first half of the 1980s with a sharp downward correction occurring in 1986 that more than reversed the impact of the second oil shock in the late 1970s. LNG price data are only available since the mid-1980s – since 1986, LNG prices have moved broadly in line with other major energy commodity prices (panel b). A major influence in the world energy market in recent years has been on the demand side, which has resulted in a rise in the prices of all energy commodities.

fig H **indexes of selected real world energy prices**
world indicator prices based on US$/physical unit



3

long term energy challenges in the APEC region

Energy is an essential input into a wide range of end use applications in the APEC stationary energy sector. Notably, industry and the residential sector together accounted for 50 per cent of total final energy consumption in the APEC region in 2004. Transport, the major activity outside the stationary energy sector, accounted for a further 28 per cent of total final energy consumption (see chapter 2). While final energy consumption is sourced from a range of fuel types, electricity use has increased particularly strongly since 1992.

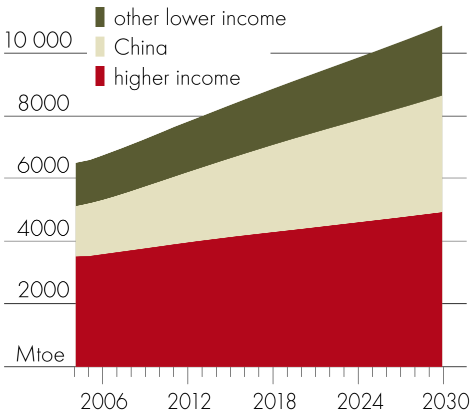
The long term energy policy objective for governments in the APEC region is to ensure the provision of energy at least cost over time, given energy technologies and resource availability and taking into account environmental impacts and economic and other risks in the outlook. In this chapter, ABARE projections for the long term energy consumption growth path in the APEC region are presented and some major challenges in the long term energy outlook are noted. These projections are derived from ABARE's global trade and environment model (GTEM). The GTEM framework and reference case assumptions are described in Matysek et al. (2006).

long term energy consumption projections for the APEC region

The long term energy requirements of the APEC region are projected to be substantial, particularly given projected strong growth in China. ABARE has undertaken several major studies in recent years on economic and policy issues relevant to world energy markets.

ABARE projections to 2030 for total primary energy consumption in the APEC region are presented in figure I. In aggregate, APEC primary energy consumption is projected to increase by 67 per cent, from around 6500 Mtoe in 2004 to almost 10 900 Mtoe in 2030 – this is slightly above the APERC (2006) projection of 10 300 Mtoe in 2030.

It is assumed that there will continue to be significant variation in energy consumption growth rates between APEC economies with, most notably, relatively strong fig I **ABARE reference case projections for total primary energy consumption in the APEC region**



growth in China. Between 2004 and 2030, total primary energy consumption is projected to increase on average by 2.0 per cent a year in the APEC region – 1.3 per cent for higher income APEC economies, 3.3 per cent for China and 1.9 per cent for other lower income economies (overall, 2.7 per cent for lower income APEC economies).

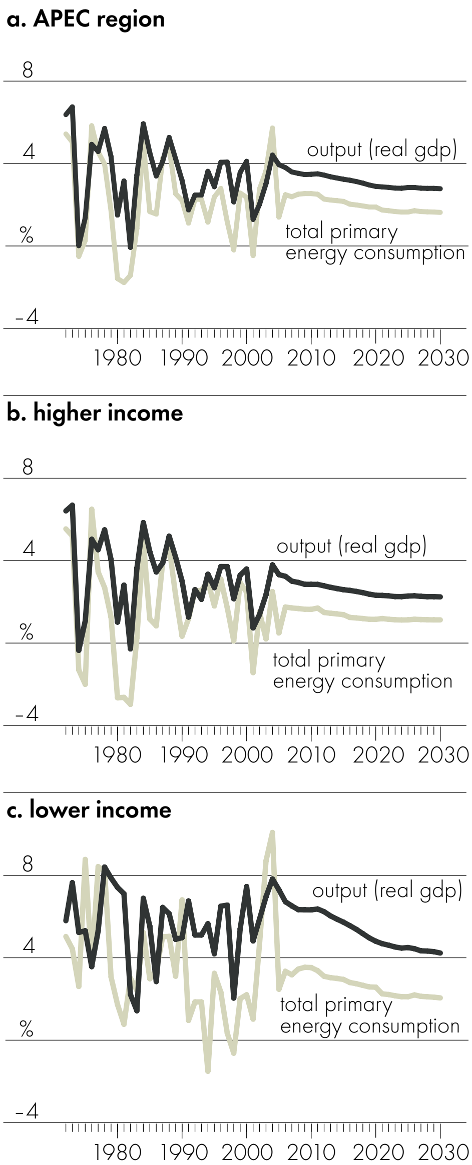
Reflecting these divergent growth rates, the share of higher income economies in total primary energy consumption in the APEC region is projected to fall from 54 per cent in 2004 to 45 per cent in 2030. Within the lower income group, the energy consumption share for China is projected to increase from 25 per cent in 2004 to 34 per cent in 2030. The energy consumption share for other lower income economies is projected to remain around 21 per cent.

The GTEM reference case incorporates a moderate level of technological change, including energy efficiency technology adoption (Matysek et al. 2006). Both output and primary energy consumption growth rates in the APEC region over the historical period 1972–2004 and projection period 2004–30 are presented in figure J. Over the projection period, annual growth rates for output (or real GDP) exceed annual growth rates for total primary energy consumption, reflecting to some extent the adoption of energy efficiency technologies. Fossil fuels remain the dominant source of energy over the outlook period. Market volatility is indicated by the fluctuations in annual growth rates over the historical period (see chapter 2 for some further discussion of the historical experience).

energy security challenges

In general terms, energy security refers to the adequate and reliable supply of energy at reasonable prices in order to sustain economic growth. From an energy security perspective, it is important to consider long term energy challenges that relate to:

fig J **APEC output and primary energy consumption growth rates**
ABARE reference case projections; excludes Russia before 1992



» **long term energy requirements** – to meet the projected growth in APEC energy requirements over the longer term at reasonable prices

» **temporary energy supply disruptions** – to manage the risks and costs of disruptions to APEC energy supply over a short to medium term timeframe.

energy resource availability and import dependence

An assessment of major long term energy challenges in the APEC region in meeting projected trend growth in energy consumption and managing fluctuations around this long term trend needs to take into account issues relating to dependence on fossil fuels in energy consumption, the distribution and size of world energy resources, and APEC energy self sufficiency or import dependence. Key issues include:

» **reliance on fossil fuels in energy consumption and world energy resource availability** – around 90 per cent of APEC primary energy consumption is sourced from fossil fuels but resource availability varies widely. Coal resources are relatively abundant compared with either gas or oil resources – at the end of 2005, the reserves to production ratio was around 155 years for coal, 65 years for gas and 41 years for oil (BP 2006; production data differ slightly from the IEA). World proved reserves for oil and gas are concentrated in the relatively high risk regions of the Middle East and Africa. It should be noted that there are estimated to be substantial subeconomic gas resources that are likely to become economic over the coming decades (see, for example, IEA 2006b).

» energy self sufficiency and resource availability in the APEC region – APEC energy production accounts for around 90 per cent of primary energy consumption, reflecting significant oil imports (see table 15 in appendix A). The APEC region accounts for around 50 per cent of world proved coal reserves, but only 12 per cent and 7 per cent of the world's proved reserves of gas and oil, respectively (based on 2005 data; see table 16 in appendix A).

The APEC region's increasing oil import dependence, or declining oil self sufficiency, is an important energy security risk reflecting both demand side and supply side aspects of the oil market:

» demand side aspects – oil dependence is a feature of APEC economies, particularly in the transport sector where there are limited substitution possibilities over the short to medium term, but agriculture and energy intensive manufacturing activities are also highly reliant on oil inputs.

» supply side aspects – oil, together with other major fuel types, are nonrenewable resources that need to be discovered before production may proceed, which increases uncertainty in any medium to longer term outlook assessment; in addition, world oil reserves and production are concentrated in relatively high risk regions, with the prospect of increasing market concentration over the longer term.

Assuming world oil consumption continues to rise over the medium to longer term, the global distribution of oil production will shift toward the distribution of proved reserves – that is, the share of the Middle East will rise – although the timing of this shift will be influenced by new project developments associated with existing reserves, new discoveries made outside the Middle East, and a change in economic conditions that enables currently uneconomic reservoirs or deposits to be reclassified as economic. The development of nonconventional sources, particularly oil sands in Canada and 'gas to liquids' projects, will also contribute to future oil supply (see IEA 2006b for further information).

Given the level of historical volatility sourced from this region, the likelihood of a significant increase in the concentration of proved reserves and production in the Middle East for oil represents an important energy security risk to the APEC region, including both the risk of a higher than expected long term oil price path (with flow-on effects to other energy prices) and the risk of oil supply disruptions.

energy market concentration

There are several features of the energy market that have the potential to increase the risk exposure of economies to sustained changes in relative energy prices as well as to temporary energy supply disruptions. These include:

- **concentration in fuel types** – heavy reliance on a specific fuel type in energy consumption, particularly in major end use applications;
- **concentration in fuel sources** – heavy reliance on a specific geographic region for energy supply, particularly in high risk locations; and
- **concentration in energy infrastructure and transport networks** – heavy reliance on a specific energy infrastructure facility such as a single oil or gas pipeline, or a transport network where there are critical chokepoints such as key sea lanes.

Specialisation in energy markets – whether in production, processing, distribution or transport – reflects the outcome of past decisions whereby energy requirements in various end use applications may have been met in a relatively cost effective manner, at least in terms of direct costs. From an energy security perspective, specialisation will continue to be economic if the expected benefits – such as access to cheaper fuel, established technologies and economies of scale – outweigh the expected costs and risks – such as the risk that energy costs will be substantially higher than expected over the longer term, including the impact of any temporary market disruptions.

energy infrastructure investment requirements

A further challenge for energy policy makers in the APEC region is the substantial investment in energy infrastructure that will be required to meet the projected growth in energy consumption in the APEC region. APERC (2006) examined APEC energy investment requirements over the outlook period to 2030. APERC estimates that APEC economies will require between US$6.0 trillion and US$7.6

trillion over the period to 2030, with electricity generation and transmission accounting for around 60 per cent of total energy investment requirements. APERC found that requirements for energy infrastructure investment may be particularly large in APEC economies that are at an early stage of development and experiencing strong economic growth. APERC further notes that financing energy projects will pose challenges to energy industries throughout the region.

energy supply disruptions

Energy supply disruptions may occur at any point in the energy supply chain and originate at a range of geographic locations affecting one or more fuel types. Disruptions may occur in isolation or simultaneously. Temporary energy supply disruptions may be caused by a range of factors, including:

- war, civil unrest, acts of terrorism or piracy on key sea lanes – these factors may disrupt energy exploration, production, processing or transport activities, with the potential to have a major impact on world energy markets
- natural events – events such as earthquakes may cause major energy infrastructure damage, although the damage typically occurs at the local or regional level
- accidents or technical factors – events such as plant breakdown may disrupt energy supply
- market factors – factors such as production volume limits or instability associated with major producer groups or cartels may have significant implications for the world energy market
- policy factors – factors such as the unintended consequences associated with energy market intervention may distort energy production and pricing outcomes to some extent.

If the magnitude and duration of a disruption is significant, there will be consequent direct economic costs for associated conversion and end use activities with flow-on implications for other economic activities. Any risk assessment of temporary energy supply disruptions in the APEC region requires information on the probability or likelihood of potential energy supply disruptions occurring and the damage or cost of each potential disruption. It would then be possible to assess the net economic benefits of investing in supply reliability measures that would reduce the risk and/or cost of supply disruptions.

sustainable development challenges

In the context of this study, sustainable development refers to sustained economic growth and the provision of cleaner energy whereby damage to human health and the environment caused by energy supply and use is reduced to reasonable levels given the development status of economies. In general terms, developed economies tend to place a higher value on the environment than developing economies, which influences the assessment of tradeoffs between the costs of investing in energy efficiency and cleaner technologies and the benefits in terms of reducing environmental damage over the longer term.

Air pollution through the emission of various gases during energy production and consumption activities is the major form of environmental damage considered in this study. From a regional and global perspective, air pollution from energy supply and use, and the associated policy response in the APEC region, are also issues that are highly relevant to energy security assessments. Air pollution is a major source of uncertainty in the long term energy outlook both in terms of damage caused to human health and the environment with flow-on effects to economies, and the implications of any policy response for energy markets (for example, relative energy prices and the economic incentives for technology adoption and switching between fuel types and sources).

Major sources of emissions include, for example, the burning of fossil fuels in electricity generation, industrial activities and transport and, in developing economies, the use of combustible renewables and waste in the residential sector. Air pollution may have local, regional or global impacts (see, for example, World Bank 2005) and includes emissions such as:

- **particulate matter** – long term exposure to high levels of soot and small particles in the air contributes to a wide range of health effects, including respiratory diseases, lung cancer and heart disease.
- **sulfur dioxide (SO_2)** – contributes to acid rain and can damage human health, particularly in the young and elderly.
- **nitrous oxides (NO_x)** – contribute to acid rain and other acidic compounds over long distances.
- **carbon dioxide (CO_2)** – an increase in the CO_2 concentration in the atmosphere is expected to result in a higher average global temperature, with global impacts.

The aim in the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilise atmospheric concentrations of greenhouse gases at levels that will prevent human activities from interfering dangerously with the global climate (see chapter 4). Given the potentially important cross-border impacts, addressing air pollution is one of the key challenges for policy cooperation in the APEC region.

challenges in policy responses

International cooperation through the APEC forum has the potential to substantially enhance regional energy security and sustainable development prospects over the longer term. However, there are significant challenges for APEC economies in assessing and implementing policy response measures to achieve long term energy goals. In general, as noted in Hogan et al. (2005) and Curtotti et al. (2006), energy security and environmental sustainability in individual economies and the APEC region may be enhanced by considering options such as:

» **removing market impediments, including liberalising trade and investment and reducing or removing energy subsidies** – the objective of these actions is to increase the efficiency of energy markets in responding to economic change, improving access to new and enhanced energy technologies and reducing future growth in energy consumption.

» **adopting a diversified portfolio of interchangeable energy forms and energy supply sources** – this is a principal response that all economies need to consider to increase the flexibility of energy markets both within and between APEC economies and includes, for example, increased investment in domestic exploration for oil and other energy forms, investment in renewable energy technologies and investment in fuel switching systems.

» **enhancing interconnection of energy systems** – interconnection reduces vulnerability to system failure and allows resources to be used in areas that may not otherwise be economic; however, the economic viability of interconnection options need to be assessed against potential stand-alone energy projects, particularly in rural and remote areas.

» **facilitating timely investment in energy production, transport and storage facilities** – these facilities will include, for example, pipelines, other transport facilities, power stations, and electricity transmission and distribution networks.

» **facilitating investment in energy efficiency and cleaner technologies, including technology R&D, adoption and transfer** – these technologies will reduce future growth in APEC energy consumption and, either directly or indirectly, reduce damage to human health and the environment.

» sharing information – sharing energy policy experience is an effective means of developing policy ideas and superior policy strategies. Not all policy strategies will be easily transferable to other economies but many are and improved understanding of what policies can succeed in different policy settings and environments is a valuable product of sharing policy experience.

Addressing the long term energy challenges that the APEC region faces will require an appropriate policy response from APEC economies.

In particular, the expected continued strong growth in energy consumption in APEC's stationary energy sector will require a policy response that addresses both energy security and environmental sustainability. Cleaner energy supply options for electricity generation and improving energy efficiency in end use applications will remain priorities for APEC economies. New and existing technologies will need to be further developed and deployed across the APEC region in order to reduce future growth in APEC stationary energy sector consumption. Background information on the energy policy setting in the APEC region is presented in chapter 4. Chapters 5 and 6 present information on current and emerging energy efficiency and cleaner technologies for the supply side and demand side, respectively, of the APEC stationary energy sector. The remaining chapters of the report focus on barriers to investment in the development and deployment of new energy technologies, the economic rationale for government intervention in encouraging technology R&D, adoption and transfer and appropriate policy response options, with some key policy implications for the APEC forum provided in the final chapter of the report.

4

energy policy setting in the APEC region

Energy security and sustainable development have become key issues for the APEC forum. At the seventh meeting of APEC Energy Ministers (EMM7), held in the Republic of Korea in October 2005, ministers emphasised the importance of access to adequate, reliable, affordable and cleaner energy for enhancing the region's economic, social and environmental wellbeing (see box 2 in chapter 1). The ministers also encouraged cooperation to accelerate the development and deployment of technologies that allow for more efficient energy use and energy diversification, furthering the region's energy security and sustainable development.

In this chapter, background information is provided on the energy policy setting in the APEC forum, with a focus on energy security and sustainable development in the stationary energy sector. Some relevant aspects of policy initiatives in other international organisations are also noted.

APEC energy policy setting

Several main themes are apparent in energy policy development in the APEC region. These themes include the creation of competitive energy markets, providing a regulatory and legal framework that fosters private sector interest in meeting the investment requirements of the energy sector, promoting intra and interregional trade in energy, and strengthening regional dialogue in the areas of new energy technology development and demonstration of new technologies through active participation in regional technology partnerships.

Notably, at the 14th APEC Economic Leaders meeting held at Ha Noi, Viet Nam in November 2006 the economic leaders reiterated through the Ha Noi Declaration that energy security is critical for sustainable economic development. The leaders also noted that there would be challenges in meeting rapidly growing energy demands while minimising environmental effects. The declaration urges member economies to continue to work to facilitate energy investments and cross-border energy trade, to develop new and renewable energy sources and technologies to ensure cleaner use of fossil fuels, to boost energy efficiency and conservation, and to enhance emergency preparedness and to better protect critical energy infrastructure.

Energy policy development and harmonisation at the APEC regional level has been assisted by the establishment of the APEC Energy Working Group (EWG). The EWG was launched in 1990 and seeks to maximise the energy sector's contribution to the region's economic and social wellbeing, while mitigating the environmental effects of energy supply and use (see www.apec.org). The EWG is one of the most active APEC working groups – every year it proposes and conducts the largest number of APEC projects among APEC working groups.

In areas of energy policy development, the EWG responds to energy policy initiatives set forth by APEC energy ministers that meet at regular intervals. For example, in 1996, APEC energy ministers considered and endorsed fourteen nonbinding energy policy principles, designed to provide policy guidance to individual APEC economies and to coordinate and harmonise energy policy development efforts across the APEC region (see box 3). At the most recent meeting, held in the Republic of Korea in October 2005, APEC energy ministers encouraged APEC economies to respond to the challenges of meeting the region's energy supply and demand through promoting energy efficiency and conservation, expanding cross border trade in energy, attracting energy sector investment, and accelerating energy technology development.

The APEC policy approach to energy security, sustainable development and energy technology development and deployment is outlined below.

APEC energy security initiative

The APEC Energy Security Initiative (ESI) includes short term measures to respond to temporary energy supply disruptions as well as longer term policy responses to energy security concerns (see www.apec.org). The Energy Security Initiative originated in 2000 and was endorsed by APEC leaders and ministers in October 2001. The Energy Security Initiative has since been enhanced and expanded through the CAIRNS Initiative and APEC Action Plan to Enhance Energy Security.

The longer term policy responses options to energy security concerns, which are most relevant to this study, are wide ranging and take into account sustainability and environmental impacts. Longer term responses include the following categories:

» energy investment – implement the recommendations of the *Energy Investment Report: Facilitating Energy Investment in the APEC Region*, recognising box 3 **agreed nonbinding energy policy principles of APEC economies**

1 Emphasise the need to ensure energy issues are addressed in a manner which gives full consideration to harmonisation of economic development, security and environmental factors.

2 Pursue policies for enhancing the efficient production, distribution and consumption of energy.

3 Pursue open energy markets for achieving rational energy consumption, energy security and environmental objectives, recommending action in the appropriate forum of APEC to remove impediments to the achievement of these ends.

4 Recognise that measures to facilitate the rational consumption of energy might involve a mix of market based and regulatory policies, with the relative components of the mix being a matter for the judgment of individual economies.

5 Consider reducing energy subsidies progressively and promote implementation of pricing practices which reflect the economic cost of supplying and using energy across the full energy cycle, having regard to environmental costs.

6 The regular exchange of experience on the various policies being used by member economies to achieve more rational energy consumption.

7 Ensure that a least cost approach to the provision of energy services is considered.

8 Promote the adoption of policies to facilitate the transfer of efficient and environmentally sound technologies on a commercial and nondiscriminatory basis.

9 Encourage the establishment of arrangements for the development of human resource skills relevant to the application and operation of improved technology.

10 Enhance energy information and management programs to assist more rational energy decision making.

11 Encourage energy research, development and demonstration to pave the way for cost effective application of new, more efficient and environmentally sound energy technologies.

12 Promote capital flows through the progressive removal of impediments to the funding of the transfer and adoption of more energy efficient and environmentally sound energy technologies and infrastructure.

13 Promote cost effective measures which improve the efficiency with which energy is used but reduce greenhouse gases as part of a suggested regional response to greenhouse gas reductions.

14 Cooperate, to the extent consistent with each economy's development needs, in the joint implementation of projects to reduce greenhouse gas emissions consistent with the Climate Change Convention.

Source: 1996 APEC Energy Ministerial Meeting (www.apec.org) the important contribution of the private sector and financial community in developing the recommendations; reaffirm our commitment to encourage the implementation of best practices previously endorsed for implementation in the natural gas and electricity sectors.

- natural gas trade – support the creation of a competitive and transparent market for gas trade and encourage member economies to move toward best practice as identified in *Facilitating the Development of LNG Trade in the APEC Region*, recognising the important contribution of the private sector in developing these best practice principles; continue work to improve the security of natural gas supply by identifying vulnerabilities, supporting trade promotion and establishing convenient information links to gas market data available in existing data systems.
- nuclear power – interested member economies are encouraged to cooperate on the nuclear framework as endorsed by the EWG; security, seismic and health concerns, including transborder effects, should be adequately addressed.
- energy efficiency – implement an energy efficiency Pledge and Review Program that includes ways to monitor the implementation of policies and programs; participate in the Energy Standards and Labelling Cooperation Initiative and the web based APEC Standards Notification Procedure aimed to facilitate trade in efficient energy using equipment used within the region; and encourage broadening the scope of work on energy efficiency to include other energy intensive sectors, and to monitor the development of new technologies that could have significant impacts on, and synergy with, energy efficiency and conservation.
- renewable energy – the EWG is to continue its work under the 21st Century Renewable Energy Development Initiative (REDI), working closely with the EWG Business Network and the APEC business and research communities; EWG activities in this area are coordinated by the Expert Group on New and Renewable Energy Technologies; REDI comprises eight 'collaboratives', each focusing on an aspect of renewable energy and led by one member economy; REDI projects have included building a web based tool to facilitate renewable energy project development, developing a renewable energy financial roadmap and a strategy for a climate neutral APEC city, and assessing renewable energy training and accreditation needs for the APEC region.
- hydrogen – implement the recommendations identified in the *Interim Framework Document on Hydrogen and Fuel Cells* that highlights the potential for a hydrogen economy in the APEC region.

- **methane hydrates** – support research on the potential of methane hydrates as a future energy source, and direct the EWG to communicate research developments within their economies.
- **clean fossil energy** – EWG to continue its work in the areas of clean fossil energy and carbon dioxide capture and geological sequestration, working closely with the EWG Business Network and the APEC business and research communities; through the Expert Group on Clean Fossil Energy, the EWG has undertaken a number of activities to facilitate clean fossil energy, including projects on clean transport fuels, reducing carbon dioxide emissions from electricity generation and the upgrading and refurbishment of older coal fired power stations; the EWG is currently undertaking projects to identify potential geological storage sites in the APEC region and build the capacity of member economies to undertake geosequestration activities.

Further information on the Energy Security Initiative, including short term policy responses, is provided on the APEC website (see www.apec.org).

sustainable development

The APEC Economic Leaders' Economic Vision Statement at Blake Island, Seattle, in the United States in November 1993 stated, 'Our environment is improved as we protect the quality of our air, water and green spaces and manage our energy resources and renewable resources to ensure sustainable growth and provide a more secure future for our people'. This statement provides the mandate for APEC's work on sustainable development.

APEC ministers in 1996 decided that APEC senior officials should prepare an annual review of activities of sustainable development in APEC, to monitor the development and implementation of sustainable development initiatives as well as to coordinate and provide guidance to APEC forums. Accordingly, the APEC Secretariat compiles an annual overview of sustainable development work across APEC forums. Although there has been no formal meeting of the Senior Environment Officials' group since the Environment Ministers' Meeting in 1997, since sustainable development is a cross-cutting issue, implementation of the related initiatives has been carried out by the relevant sectoral forums. For example, a consolidated report on the contribution of APEC to sustainable development was presented to the World Summit on Sustainable Development (WSSD) in 2002 and acknowledged by the ministers and leaders.

The APEC High Level Meeting on Sustainable Development was held in Santiago, Chile on 20–21 July 2006. The conclusions and recommendations of the meeting included:

» to encourage APEC Working Groups to coordinate their work on sustainable development through the exchange of information and ongoing cooperation between and among APEC economies;

» to improve the exchange of information between APEC and other international organisations, such as the UN-CSD, the WTO, the OECD and the World Bank; and

» to consider civil society participation and dialogue in future work on sustainable development.

The above information on the APEC policy approach to sustainable development is taken from the APEC website (see www.apec.org for further information).

accelerating energy technology development

The following is an extract from the Ministers' Declaration at the Seventh Meeting of APEC Energy Ministers (APEC 2005, pp. 4–5):

22 The development and uptake of energy technologies will help APEC economies bring supply and demand into balance through increased production, diversification and efficiency and will reduce the environmental impact of energy production and use. It is estimated that adopting more advanced energy technologies could reduce growth in energy consumption of the region's electricity sectors by forty per cent to 2030, saving more than 500 million tonnes of oil equivalent. APEC economies are global leaders in the development of many energy technologies, and the challenge is to leverage and build on this strength through effective cooperation and collaboration.

23 To accelerate energy technology development, and to build on EWG efforts since EMM6:

- we direct the EWG to increase its cooperative activities to support the development and uptake of technologies for new and renewable energy, clean fossil energy including clean coal, carbon capture and storage, hydrogen and fuel cells, and methane hydrates; and
- recognising the growing importance of nuclear energy in the APEC energy mix, we encourage interested APEC economies to join the ad

hoc group on nuclear energy, and to progress activities identified in the nuclear framework endorsed at EWG27, to support nuclear power with ensuring optimal safety, security, seismic, health and waste handling, including transborder effects.

Mechanisms to enhance energy technology transfer and adoption already exist within the APEC forum. For example, the EWG seeks to promote a multilateral approach to the development and transfer of energy technology, exchange, application and deployment. This objective extends to addressing impediments to energy infrastructure investment in the region, and identifying ways to mobilise private capital.

The EWG also facilitates linkages between government officials, financial sector representatives and energy business representatives (APEC 2004). The EWG engages with the private sector principally through the EWG Business Network (EBN), a consortium of business representatives, which regularly advises the EWG on energy policy issues and the EWG work program. The EWG Business Network also facilitates meetings between energy policy makers and business representatives. The EWG Business Network is set to play an important role in mobilising the investment requirements for the APEC energy sector over coming decades. The energy sector in APEC economies faces significant challenges in mobilising private capital and international financial resources to fund an estimated US$3.4–4.4 trillion in energy sector investments over the next two decades (see www.apec.org). It is expected that the engagement of business representatives through the EWG Business Network will help facilitate investment in the energy sector.

The APEC EWG has also established subgroups that can facilitate technology transfer and adoption. For example, the Expert Group on Clean Fossil Energy (EGCFE) has the role of gathering and sharing timely information on technical, economic and policy aspects of clean fossil energy and clean technologies within the APEC region (www.apec-egcfc.org). This information is used to facilitate and encourage commercialisation and use of environmentally sound energy technologies and processes and to facilitate cooperative activities, including demonstration projects in APEC economies.

APEC policy directions on energy technology development and deployment are also included in the APEC Energy Security Initiative, as noted earlier in this section.

other international organisations

Other international organisations where there is active participation by a number of APEC economies in energy policy cooperation initiatives include the International Energy Agency, ASEAN, the Asia Pacific Partnership on Clean Development and Climate, the East Asia Summit, the Group of Eight (G8), and the Meeting of G20 Finance Ministers and Central Bank Governors (see table 2). Some relevant policy aspects are briefly noted in this section.

International Energy Agency (IEA)

Under the agreement forming the IEA in 1974, members committed to sharing energy information, coordinating energy policies and cooperating in the development of rational energy programs. To this end, the IEA has provided energy policy

table 2 **APEC member economy participation in selected IEA implementing agreements and initiatives**

	climate technology initiative	fluidised bed conversion	IEA clean coal centre	fusion power	IEA geo -thermal energy	hydrogen implementing agreement	hydro-power
Australia			X	X	X	X	
Brunei Darussalam							
Canada	X	X	X	X	X	X	X
Chile							
People's Republic of China			X	X	X		X
Hong Kong, China							
Indonesia							
Japan	X	X	X	X	X	X	X
Republic of Korea	X	X	X	X	X	X	
Malaysia							
Mexico					X		
New Zealand			X		X	X	
Papua New Guinea							
Peru							
Philippines							
Russian Federation				X			
Singapore							
Chinese Taipei							
Thailand							
United States	X		X	X	X	X	
Viet Nam							

Source: www.iea.org/Textbase/techno/index.asp advice to both members and nonmembers and has assisted member economy policy development through the establishment of over forty international cooperation and collaboration agreements covering technology R&D, deployment and information dissemination (see table 3).

Association of South East Asian Nations (ASEAN)

In the ASEAN region, the broad thrust of energy policy is to enhance ongoing market reform and increase the opportunities for cross border energy trade. Part of the market reform program is to wind back energy subsidies through discontinuing price controls and undertaking associated tax reform, and continue the deregulation of state monopolies. An increase in cross border energy trade is being pursued through the Trans ASEAN Energy Network, comprising the ASEAN Power Grid and the Trans ASEAN Gas Pipeline. For example, five cross border electricity interconnection projects between ASEAN countries are currently being developed, with policy and the framework for crossborder interconnection and trade in electricity currently being considered. In the gas sector, several interconnection projects have been successfully completed, including a gas pipeline interconnection between Malaysia and Thailand, achieved through a joint venture gas field development. Similar projects are planned for the Philippines and Indonesia.

United Nations Framework Convention on Climate Change (UNFCCC)

Under this convention most APEC economies, together with almost all other economies, have committed to the objective to achieve stabilisation of greenhouse gas

table 3 **selected APEC members with renewable energy targets**

Australia	9500 GWh of electricity a year by 2010
New Zealand	30 PJ of new capacity (including heat and transport) by 2012
Philippines	An increase in renewables to 4.7 GW of total existing capacity by 2013
Thailand	All new fossil fuel based generating capacity to be associated with renewable capacity of at least 5 per cent of installed capacity from 2011 onwards.
Singapore	Installation of 50000 m^2 of solar thermal systems by 2012 and complete recovery of energy from municipal waste
People's Republic of China	Installation of 290GW of hydroelectricity, 30GW of wind, 20 GW of biomass, and 2 GW of photovoltaic capacity by 2020

concentrations in the atmosphere at a level that would prevent dangerous human induced interference with the climate system. To achieve this objective, all Parties to the Convention are subject to a set of general commitments, which place a fundamental obligation on both industrialised and developing economies to respond to climate change. Under this framework, several APEC members, including Canada, Japan, New Zealand, and the Russian Federation, have made specific commitments to abate the emission of greenhouse gas to the atmosphere under the Kyoto Protocol. The Kyoto Protocol entered into force in 2005, and is influencing energy policy in these member economies.

Asia Pacific Partnership on Clean Development and Climate (AP6)

The Asia Pacific Partnership on Clean Development and Climate (AP6) consists of five APEC members – Australia, China, Japan, the Republic of Korea and the United States – and India, and was brought into effect on 28 July 2005. A key focus of the partnership is to facilitate the development, diffusion, deployment and transfer of existing, emerging and longer term cost effective cleaner, more efficient technologies (APPCDC 2006b). The partnership aims to address energy, air pollution and climate change issues within the context of continued economic development and poverty alleviation.

A key aim of the partnership is to use expertise and experience in industry, research communities and governments in bringing cleaner technologies to markets. Actions under the partnership are anticipated to include technology based research, development and demonstration, exchange of information and expertise, dissemination of best practice technologies and provision of a forum for high level policy dialogue (APPCDC 2006). Eight public–private sector taskforces have been established, focusing on: cleaner use of fossil energy; renewable energy and distributed generation; power generation and transmission; steel; aluminium; cement; coal mining; and buildings and appliances.

East Asia Summit (EAS)

The East Asia Summit is a forum of leaders for dialogue on broad strategic, political and economic issues in east Asia. The first summit was held on 14 December 2005 in Kuala Lumpur, Malaysia, and was attended by the heads of state/government of ASEAN, Australia, China, India, Japan, the Republic of Korea and New Zealand. At the second summit, held in the Philippines in January 2007, policy direction for the energy sector was given in twelve measures contained in the Cebu Declaration on East Asian Energy Security. This declaration commits signing member states to promoting cleaner and lower emission technologies that allow for the continued use of fossil fuels and in particular promote the development and use of clean coal technologies and international environmental cooperation toward mitigating global climate change.

OECD Group of Eight (G8) forum

The forum's first annual meeting was held in 1975 and attended by the heads of government of France, Germany, Italy, Japan, United Kingdom and the United States. This meeting was held in response to the oil price shocks and subsequent global recession of the early 1970s. The forum became known as the Group of Seven (G7) with the admission of Canada in 1976, and the Group of Eight (G8) in 1997 with the admission of the Russian Federation.

The G8 summit is an important forum where multilateral energy policy development has been complementary to efforts in other international forums and partnerships. Energy was a key theme at both the Gleneagles and St Petersburg Summit meetings in 2005 and 2006 respectively. At these meetings, forum members committed to policy principles that help to address climate change, clean energy and sustainable development. In developing energy policy under these broad themes, member economies committed to working closely with appropriate partnerships, and institutions including the International Energy Agency and World Bank.

G20 forum

The G20 is an informal forum, created in 1999 in response to a growing recognition that key emerging market economies were not adequately included in the core of global economic discussion on key issues related to global economic stability and governance. The members of the G20 include the finance ministers and central bank governors of nineteen countries (including nine APEC members): Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, the Russian Federation, Saudi Arabia, South Africa, the Republic of Korea, Turkey, the United Kingdom and the United States of America. The European Union is also a member, represented by the rotating Council presidency and the European Central Bank.

The most recent annual meeting of the G20 was held in Melbourne in late 2006. A key focus of the Melbourne dialogues was international energy markets, with key themes including, for example, achieving lasting energy security and addressing global challenges such as climate change; creating efficiencies and encouraging new technologies, and allowing knowledge and resources to flow across borders; and further reforming of energy price subsidies to ensure fiscal sustainability, improving market efficiency, and better targeting for poverty alleviation. A key outcome of the meetings was the recommendation that the Joint Oil Data Initiative (JODI) be extended to other energy sectors, such as natural gas, and for further work on incorporating a common definition of energy reserves.

policy setting for electricity generation in the APEC region

To create competitive environments for energy trade, vertically integrated state owned energy companies across the APEC region are being progressively unbundled – through the separation of generation, transmission and distribution assets. Deregulation in the sector is leading to opportunities for the creation of a competitive framework and the participation of private sector investment into the sector. Many APEC economies have adjusted, or are in the process of adjusting, legal frameworks to enable private sector participation in the electricity market.

Competitive environments have allowed increased levels of intra and interregional trade in electricity, through the interconnection of existing electricity supply grids within and between many APEC economies. The two prime motivators for policies that enhance intra and interregional trade in electricity are energy security and economic efficiency. Interconnection of electricity networks can avoid the costs of maintaining high reserve margins to meet peak loads, and forestalls the need for additional generating capacity, and helps achieve economies of scale in power production, as excess power can be exported. In addition, interconnection can help achieve policy goals of governments to improve air quality. For example, remote hydroelectricity resources can be tapped and exported to other electricity grids through interconnection, and potentially displace fossil fuel based power.

The next section outlines the policy framework in the APEC region for each of the main modes of electricity generation, including electricity generation based on fossil fuel use, nuclear power, and renewable energy sources. The energy policy setting in several subregions of the APEC area, with an emphasis on electricity generation, is presented in appendix C – subregions include north America, Australia and New Zealand, south east Asia, south America, north east Asia, China and the Russian Federation.

fossil fuels

The APEC region will require a continuing use of fossil fuels to meet its future energy requirements. However, owing to rising levels of particulate pollution and the effects of global warming on the environment, continued use of existing conventional energy conversion systems will require the adoption of cleaner fossil fuel based technologies over the longer term. In recognising this, many APEC economies are orienting energy policy toward encouraging the development and deployment of cleaner fossil fuel based technologies. These technologies include combined cycle gas turbines, clean coal technologies and in suitable applications, cogeneration.

nuclear power

The United States, Japan and the Republic of Korea are the only high income APEC economies with a specific policy to increase the use of nuclear power. In the United States, the Nuclear Power 2010 program, launched in 2002, aims to facilitate the development and operation of new nuclear power plants through streamlining the regulatory approvals process. Key parts of the program include the Combined Construction and Operation Licence. Additional incentives for the establishment of nuclear power plants is provided in the Energy Policy Act (EPACT) of 2005 which incorporates a production tax credit of 1.8 cents per kWh for up to 6000 megawatts of generating capacity from nuclear power plants for a period of eight years and loan guarantees for up to 8 per cent of the total project cost (IEA 2006a). In Japan, the new national energy strategy announced in May 2006 indicates a target share for nuclear power in the electricity generation mix of more than 30 per cent to 2030, compared with 26 per cent in 2004. Likewise the Republic of Korea has set an indicative target for nuclear power generating capacity to reach 27 gigawatts in 2017 compared to 17 gigawatts in 2006.

Other higher income APEC economies with active nuclear power programs include Canada and Chinese Taipei. In both these economies there has been renewed interest in nuclear power, in part to meet future electricity demand, and to reduce greenhouse gas and air pollution emissions in the case of Canada and as part of broader energy diversification policy in the case of Chinese Taipei.

Lower income countries with nuclear power programs include the Russian Federation, the People's Republic of China and Mexico. In the Russian Federation the government approved in June 2006 a new federal targeted program that aims to increase the share of nuclear power in electricity generation from 16 per cent to 25 per cent by 2030. Equally, China has a target to build 40 gigawatts of nuclear capacity by 2020. In Mexico, the government recommended in November 2006 that the country build a second nuclear power plant, in order to reduce the reliance on oil and gas fired generation.

Nuclear power development in the APEC region will be assisted by a range of partnerships. For example, the US sponsored Global Nuclear Partnership – a $US250 million program launched in February 2006 – aims to expand the development of nuclear energy technologies. The broad objectives of the program are to demonstrate advanced technologies that minimise nuclear waste and at the same time enhance safety. In addition APEC member economies of Japan, the Republic of Korea, and the United States are part of the eleven member Generation 4 International Forum, which aims to develop generation 4 nuclear reactor designs that can provide competitively priced electricity while addressing issues of improved nuclear safety, public acceptance, waste and proliferation.

renewable energy

Most governments in APEC economies have established renewable energy policies to foster greater use of renewable energy in the energy mix. These policies in general are implemented to support all renewable energy technologies but are augmented in some instances by programs that favour the development of a particular renewable energy technology. For example, China applies the Wind Power Concession Program, which incorporates guaranteed feed-in prices to electricity grids for electricity produced from onshore wind turbines to foster increased development of wind power. Similarly, Australia's Solar Cities program focuses specifically on solar power development in urban settings through a partnership approach involving local communities, the private sector and the Australian Government.

A range of mechanisms is available and currently used to increase the adoption of renewable energy in the APEC region. These mechanisms include research and development funding to initiate research into renewable energy technology, capital grants for demonstration projects, third party financing of demonstration projects, and investment tax credits to establish pilot projects. To encourage greater use of power sourced from renewable energy sources, policy measures are available that establish obligations for the use of renewable energy in the energy mix through renewable energy portfolio standards, consumer grants and rebates, and guaranteed feed-in prices for renewable energy. Favourable link-in tariffs, where renewable energy systems are linked to the grid, are recognised as being necessary for many renewable energy technologies to allow grid supplied renewable energy to be taken up in the generation mix (McCracken 2006). There is a continuing need to encourage the long term commercial viability of renewable energy without long term requirements for subsidies and other government support.

While renewable energy development is mainly fostered through promoting private sector involvement, and the development of the sector is predominantly market driven, some exceptions to this apply. Mandatory renewable energy targets have been established in a limited number of economies in the APEC region, and backed by policy instruments (table 3). For example, under China's Renewables Energy Law, China plans to install 290 gigawatts of hydroelectric capacity, together with 30 gigawatts of wind, 20 gigawatts of biomass and 2 gigawatts of solar photovoltaic capacity by 2020. Also, Australia's Mandatory Renewable Energy Target sets a target of 9500 GWh of additional renewable energy generation a year by 2010, bringing Australia's renewable share of electricity consumption to 11.1 per cent in 2010 (Heaney et al. 2005). In addition, while not a mandatory target, the ASEAN region has established a policy to increase renewable electricity in ASEAN's power generation mix to at least 10 per cent by 2009.

Policies on renewable energy in member economies are augmented by initiatives taken in international forums, designed to accelerate the uptake of renewable energy technologies. For example, in the Asia Pacific Partnership on Clean Development and Climate (APPCDC), a taskforce on renewable energy and distributed generation has been established that is designing action plans for the sector – this taskforce is addressing market and technical impediments to the wider uptake of renewable energy in member economies, including in areas of cost competitiveness, awareness of technology options, intermittency and the need for electricity storage.

The new and renewable energy sector has been recognised as an important sustainable way of alleviating energy shortages and increasing access to education to children that otherwise spend time collecting biomass fuel to meet household energy requirements. For example, the World Bank and Asian Development Bank actively promote renewable energy in developing economies, including those in the APEC region, by providing finance for projects through various funding arrangements. The Clean Development Mechanism (CDM) established under the Kyoto Protocol is an example of one such mechanism.

The influence of multilateral aid agencies in influencing policy development for renewable energy technologies in lower income APEC economies is significant.

For example, funding under the Global Environment Facility, a World Bank program established in 1991 to promote programs in developing countries that protect the global environment, has provided financial assistance to a significant number of renewable energy and climate change related projects in most low income APEC economies. Support from the facility has helped these economies to create enabling policy frameworks and build capacity for understanding, using renewable energy technologies and financing to lower the cost of renewable energy supply. The Asian Development Bank similarly is aiding policy development in the APEC region, through providing funding for renewable energy technologies. Support for these agencies from higher income APEC members is assisting in diffusing technology to economies that would otherwise not have the financial or institutional capacity to adopt.

energy efficiency and conservation policies in the APEC stationary energy sector

All of the economies in APEC have undertaken or are undertaking energy efficiency programs of some form. Many programs are directed at raising the efficiency of energy and electricity use in residential and commercial buildings. Others are directed at raising the efficiency of energy intensive industry or transport. Still others are broadly informational and training efforts, such as standards and labelling, to raise the awareness of society of the issue and facilitate efficiency improvements across a range of sectors. Some background information on energy conservation and energy intensity targets in China is provided in box 4.

energy efficiency standards and labelling

Energy efficiency standards and labels have been recognised by APEC energy ministers as a promising approach to raising energy efficiency. At their meeting in San Diego in May 2000, APEC energy ministers endorsed an energy standards and labelling cooperative initiative to promote this approach. Developed under the auspices of the APEC Energy Working Group, the energy standards information system (ESIS) (www.APEC-ESIS.org) is a collaborative web based information resource on equipment and appliance energy standards. The primary objectives of ESIS are to provide up to date information about appliance and equipment energy standards and regulations, and provide links to experts and information across APEC and partner economies. The ESIS program also provides an effective platform to establish 'communities of practice' for experts and officials to meet and exchange information and experience.

box 4 China – energy conservation and energy intensity targets

In 1997, the National People's Congress passed the Energy Conservation Law, an important step toward legitimising energy conservation as an element of Chinese policy. The law was based on the experience gained through energy efficiency programs dating back to the early 1980s, as well as the changed environment of a transitional economy. A legislative review of all laws pertaining to energy policy is currently under way, with the aim of providing greater consistency of approach in all aspects of the energy sector, including the application of energy efficiency and conservation measures.

The 11th Five Year Plan outlines strategic objectives that include doubling 2000 per person GDP by 2010 and reducing the energy intensity of GDP by 20 per cent. The National Development and Reform Commission (NDRC) has recently announced a more flexible approach, allowing for differential targets for provinces that will be dependent on the current energy intensity of industry based in each province.

The NDRC has released a list of ten key energy conservation projects in the 11th Five Year Plan period (2006–10). The ten key projects include:

- energy optimisation of large consumers of energy (iron and steel and petro-chemical industries), including the utilisation of afterheat in industries such as steel, nonferrous metals, coal, construction materials, chemicals and textiles
- energy efficient design of residential and commercial buildings – currently energy consumption per square metre is two to three times higher than more developed nations with similar climatic conditions
- the phasing in of more energy efficient lighting in commercial office space and households
- investment in technologies to enable consumers to monitor energy use more adequately.

The NDRC's development policies for a number of energy intensive sectors are aimed at curbing growth in production capacity that continues to underpin merger activity in a number of industries. There are explicit targets for the iron and steel sector to consolidate production and it is expected that the largest ten steel producers will account for 50 per cent of production by 2010, and 70 per cent by 2020. The further consolidation of many heavy industries in China may also provide the incentive for the introduction of cost effective energy efficient technologies as more energy intensive production processes are phased out.

demand response programs

The use of demand response programs is not widespread in the APEC region. For example, based on a survey by the Federal Energy Regulatory Commission (2006), only 5 per cent of customers in the United States are on some form of time based rate or incentive program. A key requirement for most demand response programs and time based rates is the availability of enabling technology.

For utilities to implement demand response and time based rates, a key requirement is metering that record use on a more frequent basis, preferably hourly. In Australia, smart metering is slowly being introduced and provides consumers with greater flexibility and potential for savings in changing energy consumption patterns. Introducing other demand technologies such as smart thermostats (thermostats that adjust room temperatures automatically in response to price changes or remote signals from system operators) would increase the amount of load that could be reduced under a demand response program.

5

energy efficiency and cleaner technologies in the supply side of the APEC stationary energy sector

There are multiple sources of energy supply to produce the electricity and heat required by the APEC stationary energy sector. These sources include the combustion of fossil fuels; nuclear energy; and renewable sources of energy, including biomass combustion, and harnessing hydro, geothermal, wind and solar power.

As indicated in chapter 2, figure C (panel b), electricity is a significant part of total stationary energy supply in the APEC region (28 per cent in 2004), with the remainder sourced from coal, oil, gas, renewable sources and commercial heat. From the same figure it is also clear that electricity is over time increasing its share of the APEC stationary energy consumption mix. Accordingly, much of the international effort to provide cleaner energy supply options is focused on improving conversion technologies in the electricity generation sector.

Hence, the focus in this chapter is predominantly on energy efficiency and cleaner technologies for electricity generation, with some information on commercial heat supply technologies, including combined heat and power generation technologies. Technologies that convert energy to produce heat for industrial applications or centralised heating of buildings are discussed in the following chapter.

This chapter first highlights the regional differences in the pattern of final stationary energy consumption and electricity and heat generation between higher and lower income APEC economies. Supply options to meet the electricity requirements of the region over the longer term are then outlined.

electricity generation in higher and lower income APEC economies

electricity use in final stationary energy consumption

Over the period 1992–2004, growth in stationary energy consumption was relatively faster in lower income APEC economies (excluding the Russian Federation) than in higher income economies, at annual rates of growth of 2.7 per cent and 1.3 per cent respectively (table 4). The collapse of the Soviet Union and the subsequent adjustment phase in the Russian Federation moderated the growth of stationary energy consumption in the lower income APEC region over the period 1992–2004. For example, APEC's share of world stationary energy use declined rapidly after the collapse of the former Soviet Union, falling from 63 per cent in 1992 to 55 per cent by 1997 – a level that was maintained over the period 1997–2004.

The energy mix used for stationary energy purposes in the APEC region also varies significantly by income group. For example, electricity makes a larger contribution to the overall energy mix in higher income economies for all stationary energy sectors than for lower income APEC economies (figure K). This reflects a higher degree of urbanisation and more stringent air pollution standards in relation to urban air in higher income APEC economies, which has encouraged the development of decentralised electricity generation. In contrast, commercial heat energy provides a greater portion of energy supply in lower income economies, mainly

table 4 **APEC stationary final energy consumption, 1992-2004**

	energy consumption		average annual growth
	1992	**2004**	**1992–2004**
	btoe	btoe	%
APEC	2.3	2.7	1.3
higher income	1.1	1.3	1.4
lower income	1.2	1.4	1.2
lower income (excluding Russia)	0.8	1.1	2.7
– China	0.6	0.8	2.5
– Russian Federation	0.4	0.3	-2.8
– other	0.2	0.3	3.2
world	3.7	5.0	2.5
APEC share of world	63	55	

Source: IEA (2006).

reflecting the use of centralised district heating for urban households in China and the Russian Federation.

The industrial sector in lower income APEC economies uses proportionally more coal than higher income APEC economies. This reflects the wide scale use of coal fired industrial boilers in economies such as China and the Russian Federation. Higher income economies have substituted many coal fired boilers for cleaner burning gas fired and electric boilers. In addition, the share of renewable energy in the industrial sector mix has increased steadily, to around 8 per cent in higher income economies, reflecting an increased use of solid biomass for energy purposes in industrial processes and the deployment of advanced biomass combustion technologies, including deriving electricity and heat from municipal and industrial waste combustion, and biogas technologies.

The influence of income levels on the energy mix in stationary energy consumption in different sectors across the APEC region is most apparent in the residential sector. As household income levels rise, households tend to substitute from traditional biomass renewable energy sources and coal to more convenient energy sources such as electricity and natural gas. For example, only 8 per cent of household energy consumption was in the form of electrical energy in 2004 in lower income APEC economies compared with 43 per cent in higher income APEC economies (figure K).

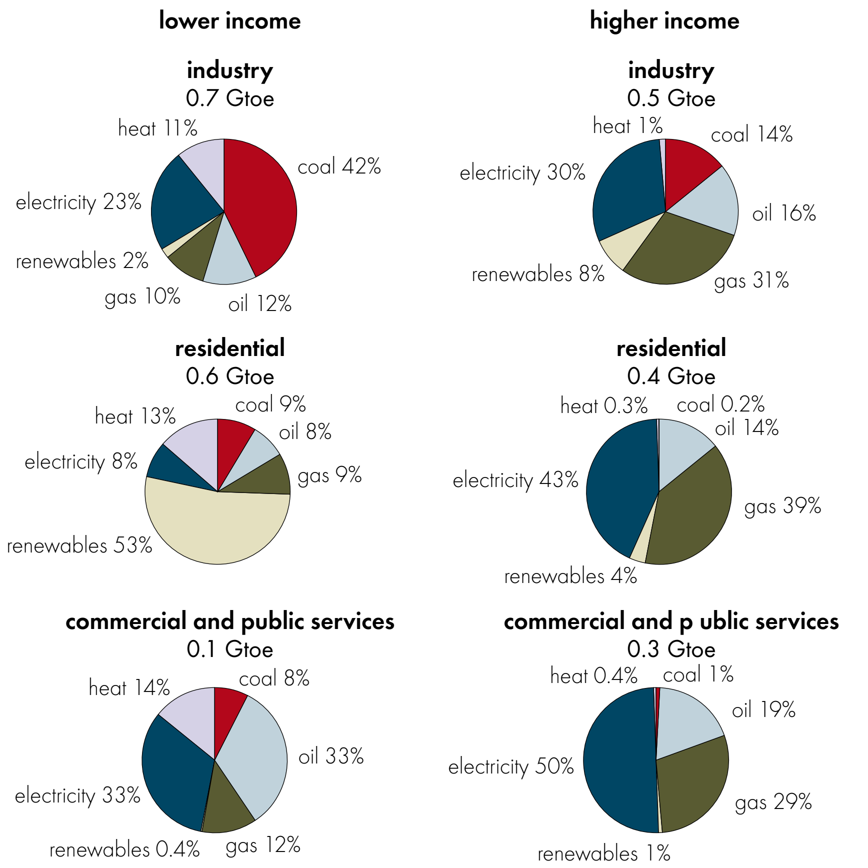
The majority of remaining energy consumption in the APEC stationary energy sector is in the commercial sector. Again, there is a significant regional difference in the pattern of energy consumption between lower and higher income APEC economies, reflecting the relative development of the sectors in the two subregions. In lower income economies, commercial heat is used widely in this sector, contributing around 14 per cent of commercial energy consumption. Also the wider use of direct combustion of fossil fuels, with proportionally more coal and oil in the mix, is also apparent in the commercial sector in lower income APEC economies.

The change in pattern of the energy mix in final energy consumption of these sectors between lower and higher income APEC economies reflects a broad trend toward urbanisation of communities across the APEC region – a catalyst for the substitution from renewable energy sources, traditionally used for cooking and heating, to commercial electricity and heat. In addition, rising incomes, that allow the purchase and use of a wide array of electrical appliances, and the broadening of government rural electrification programs in many lower income APEC economies have been factors contributing to this trend.

electricity generation

A wide array of technologies is available for electricity generation in the APEC region, ranging from coal, oil or natural gas fired generators, nuclear power technologies, and the harnessing of renewable energy to create electricity, including from hydro, geothermal, wind, solar and tidal energy sources. The technology mix adopted for electricity generation by each APEC economy is largely determined by resource endowments and economic and environmental factors.

fig K **APEC stationary final energy consumption, by income group, end use sector and energy source, 2004**

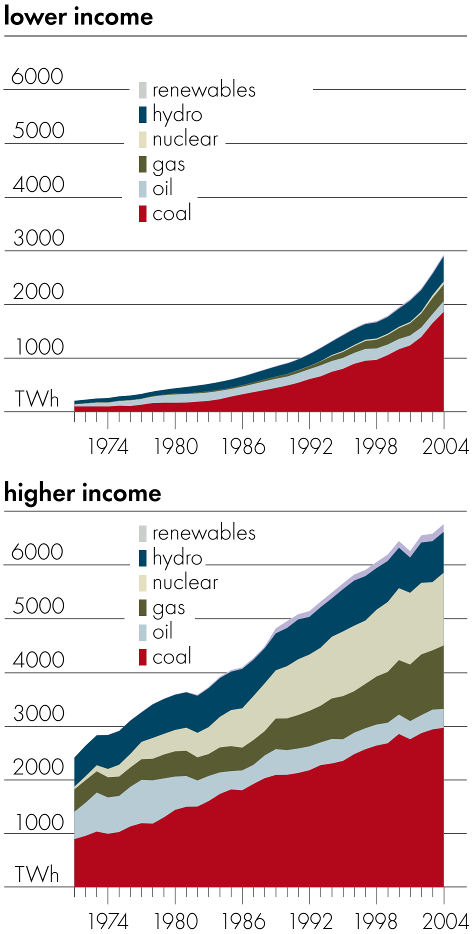


Coal and nuclear together increased their share of electricity generation in the APEC region from 40 per cent in 1971 to 62 per cent in 2004. This increase occurred mainly at the expense of oil fired and hydroelectricity generation, whose combined share fell from 44 per cent to 19 per cent over the same period. Much of the increase in coal fired power generation has occurred in lower income APEC economies (figure L), particularly in the coal resource rich economies of China, Indonesia and Viet Nam. The increase in contribution to electricity output from coal fired generation over the period reduced the risk in many APEC economies of a high dependence on oil for electricity generation.

Nuclear power generation's share of APEC electricity generation has increased, particularly in high income countries. In these countries the share of nuclear power generation in the electricity generation mix had risen to around 20 per cent in 2004. Supporting increased use of nuclear power in high income countries has been a steady rise in the capacity factor of nuclear power plants, with the global average rising from around 76 per cent in 1994 to 81 per cent in 2004, and increasing capacity at some existing power plants (IEA 2006a). While low income APEC economies have increased the share of nuclear power in their generation mix, nuclear power makes only a minor contribution to their overall electricity generation.

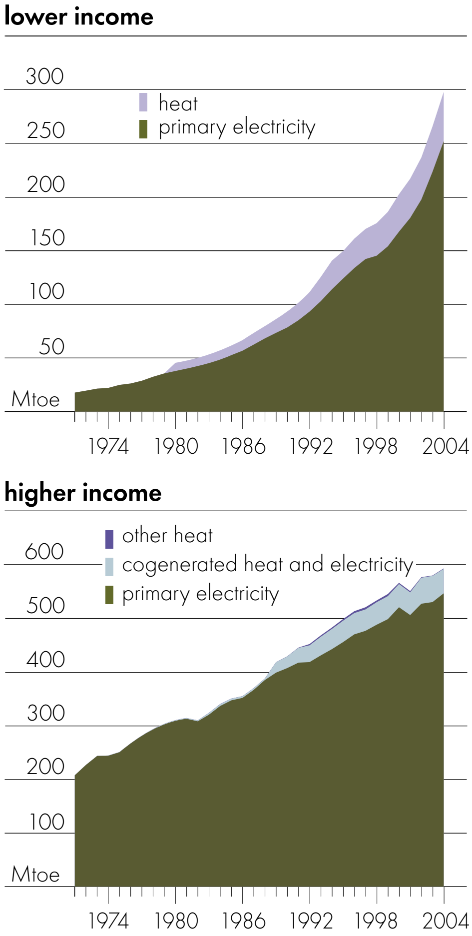
Between 1985 and 2004, gas fired generation's share of electricity generation in the APEC region

fig L **APEC electricity generation, by fuel type and income group** excludes Russia



increased from 10 per cent to 18 per cent. Over the period, the rising share of gas fired electricity generation in the electricity generation mix was driven by the relative competitiveness of the technology in comparison to coal and nuclear generation. Gas fired generation units are typically installed faster and at lower capital cost than either coal or nuclear fired power generation units. At competitive gas prices, their smaller capacity allows gas fired units to offer electricity utilities additional flexibility in siting and operation, making them highly suited to deregulated electricity markets – an emerging trend since the early 1990s.

fig M **APEC energy supply from electricity and heat**
excludes Russia



distributed power generation

Another broad trend in the energy supply mix in the APEC region has been the rising importance of distributed power in higher income APEC economies, mainly in the form of cogeneration or combined heat and electricity generation plants colocated with large energy users (figure M). These plants can be more efficient than centralised electricity generation as they do not incur losses in delivering electricity to its final use. In addition, heat energy created in generating electricity can be used directly for industrial purposes. Apart from in the Russian Federation, the use of cogeneration technologies in lower income APEC economies is limited.

In the Russian Federation there is significant use of combined heat and power plants but many plants were closed as part of the structural adjustment process that occurred after the collapse of the former Soviet Union in the early 1990s.

technology options in electricity generation

Many existing and new technology options for the stationary energy sector have the potential to make energy use in the APEC region more sustainable from an environmental perspective. For example, reducing greenhouse gas emissions in the electricity generation sector can be achieved by improving the conversion efficiency of fossil fuel powered plants, cofiring coal with biomass, adding synthetic biogas to natural gas, and installing particulate emission capture technologies in existing power stations. In addition, fuel switching from greenhouse gas intensive generation technologies, for example, by switching from coal to gas, or increasing the share of nuclear and renewable energy in the electricity generation mix, can lower economywide greenhouse gas emissions and reduce local pollution levels.

The choice of mitigation options adopted in any economy will be affected by the cost of alternative technologies, resource availability and the price of competing fuels. In this section the technology options for generating electricity and heat are discussed. This section draws on several reports, including Heaney et al. (2005), Matysek et al. (2006), and IEA (2006c). Detailed information on technology options for electricity generation is provided in appendix D.

Electricity production technologies currently deployed across the APEC region have a wide range of economic, environmental and safety attributes. For example, nuclear power results in less greenhouse gas emissions to the atmosphere than fossil fuel based power generation, but the issues of nuclear waste and safety are both important considerations for its further adoption. Equally, a continued reliance on fossil fuels for base load electricity generation over the longer term would require the introduction of more efficient fuel combustion technologies and carbon capture and storage technologies in order to address climate change related concerns.

While new renewable energy technologies are being increasingly considered as a sustainable energy source for electricity generation, a number of barriers need to be overcome to increase their contribution to the APEC region's energy supply mix. The high cost of electricity sourced from these technologies for base load operation relative to coal and nuclear electricity generation technologies is a constraint that these technologies will need to overcome before being adopted more widely.

fossil fuel based electricity generation

coal fired technologies

There is a range of existing and new coal fired electricity generation technologies at various stages of development (see appendix D).

Pulverised coal systems with a subcritical boiler are currently the most widespread coal fired technology in APEC and the world electricity market, accounting for more than 90 per cent of coal fired electricity generation capacity worldwide. Improving these technologies by incorporating a supercritical boiler is significantly increasing the thermal efficiency of these systems (to around 45 per cent compared with an average of around 36 per cent for subcritical units (AGO 2000; IEA 2002b). Supercritical power generation units are now the standard for new power generation plants in most developed regions, and comprise a significant share of generating capacity in Japan, the Republic of Korea, the Russian Federation and the United States (Coal21 2004). In developing countries, supercritical units are also being increasingly installed. For example, in China, more than 60 gigawatts of supercritical units were ordered in the two years 2005–06 (IEA 2006c). Ultra supercritical (USCPC) units, which can operate at efficiencies of up to 55 per cent (LHV), are being developed in Europe, the United States and Japan.

Pulverised coal systems are adaptable to a wide range of coal qualities but the combustion process may produce high levels of gaseous and particulate emissions if low quality coal is used. However, current and potential future emission reductions can be achieved through the application of power generation plant design features and downstream cleanup processes. Nitrous oxide emissions can be controlled within the system through the use of low nitrous oxide burners that allow coal fired power generation plants to reduce nitrous oxide emissions by up to 40 per cent. Emissions can be further lowered, if required, with the use of selective catalytic reduction (SCR). Sulfur dioxide and particulate emissions can be controlled by downstream cleanup processes such as flue gas desulfurisation (FGD).

Other coal technologies at less advanced stages of development that will have a role in sustainable electricity generation from coal includes fluidised bed combustion, integrated gasification combined cycle, lignite drying and ultra clean coal (see appendix D).

Fluidised bed technologies have an advantage over conventional pulverised coal systems in that they are able to efficiently use lower grade fuels. While the efficiency of most fluidised beds used for power generation is similar to that of conventional subcritical pulverised coal power generation plant, this technology has better environmental performance when using these fuels. Demonstration projects have been established in the United States, China and Europe for power generation plants with less than 300 megawatts capacity. Larger units are being tested at a commercial scale.

Integrated gasification combined cycle (IGCC) power generation plants are also among the cleanest and most efficient clean coal electricity generation technologies, with the added advantage of being able to use a range of carbonaceous feedstock including coal, petroleum coke, residual oil, biomass and municipal solid waste (IEA 2006c). This new type of technology for power generation has been successfully demonstrated in Europe, Japan and the United States. The high capital costs of IGCC plants relative to conventional coal fired plants and a number of technical issues are a barrier to the wider adoption of this technology. The attractive features of fuel flexibility and high efficiency do not currently outweigh the additional costs of these types of plants (IEA 2006c). Substantial research and development is required to improve the uptake of this technology.

Lignite drying and ultra clean coal technologies are both technologies that are focused on improving the quality of the fuel rather than the combustion process. Both technologies are at an early stage of development but offer substantial improvements in combustion efficiency. For example, lignite drying results in an increase in combustion efficiency and reduces greenhouse gas intensity to a level that can be similar to subcritical pulverised coal power generation plants that use black coal. Similarly ultra clean coal – a chemically pulverised coal product that is sufficiently pure to be used as a replacement for natural gas in high efficiency gas turbine generators – can be fed directly into a gas turbine combined cycle power generation plant that can operate at thermal efficiencies of greater than 52 per cent (Coal21 2004). This high efficiency rate compared with conventional coal power generation plants represents a potential reduction in greenhouse gas emissions.

gas fired technologies

Subcritical and supercritical steam systems, with conventional steam boilers and steam turbines are the most common existing technology for large scale gas fired power generation plants in developed APEC economies.

Simple cycle, or open cycle, combustion turbine power generation plants use a compressor to compress the inlet air upstream of a combustion chamber. The fuel is ignited to produce a high temperature, high pressure gas that enters and expands through the turbine section. The combustion gases in a gas turbine power the turbine directly, rather than requiring heat transfer to a water/steam cycle to power a steam turbine. The turbine section powers both the generator and compressor. The combustion turbine's energy conversion typically ranges between 30 and 35 per cent efficiency as a simple cycle (LHV).

Natural gas combined cycle (NGCC) technologies are steadily replacing simple cycle gas turbine technologies for electricity generation. NGCC power generation plants are an established technology that now account for more than 50 per cent of the worldwide market for new electricity generating capacity.

NGCC power generation plants have world's best practice thermal efficiencies of around 60 per cent (LHV) using the latest turbine design (H class) and improvements in gas turbine design are expected to raise this efficiency over time (IEA 2006c).

NGCC power generation plants have the lowest carbon dioxide emissions of all fossil fuel based generation technologies because of the low carbon content of natural gas and the high efficiency of the power generation plants. Natural gas is free of sulfur dioxide and NGCC technology reduces emissions of nitrogen oxides and particulates. The reduction in greenhouse gas emissions associated with NGCC compared with other technologies makes it an attractive option in economies where there are, or are expected to be, greenhouse gas emissions limits.

NGCC plants have lower capital costs per kilowatt and, owing to their smaller scale, have shorter construction times than competing base load power generation technologies. These attributes, together with their high energy conversion efficiency and low greenhouse gas intensity make these units a popular choice, especially in deregulated electricity markets where flexibility in design and operation is important.

On the downside, fuel costs of NGCC plants make up 60–75 per cent of total generation costs, compared with zero–40 per cent for renewable, nuclear and coal based electricity generation technologies (IEA 2006c). Hence, uncertainty about future natural gas prices is a barrier in the further uptake of this technology, as unexpected increases in input fuel costs can have a substantial impact on the economics of this technology. A sharp increase in the uptake of this type of technology could have a positive impact on international gas prices, or raise energy security concerns as a result of the need for significant gas imports.

combined heat and power (CHP)

Combined heat and power generation plants have a higher total efficiency as an integrated system than if they were two separate systems. While efficiencies from this technology can be as high as 85 per cent, the biggest challenge is locating power production near a source of waste heat, or the reverse, and matching the simultaneous demands for electricity and heat throughout diurnal and seasonal variations (APEC 2001). Further detail on this technology is provided in appendix D.

nuclear power

Light water reactors (which include the pressurised water reactor and the boiling water reactor) are the most common reactor technology – accounting for 360 of the 442 operable reactors globally – most of which were built in the 1970s and 1980s. It is expected that this technology will become increasingly dominant over the next two decades, as less efficient reactors, such as the Magnox and RBMK type reactors, are progressively replaced.

Many reactors that have been built since the early 1990s or are planned or under construction are advanced pressurised water reactors and advanced boiling water reactors, so-called generation 3 reactors (IAEA 2006). The advantage of generation 3 reactors over earlier designs is that they incorporate passive safety measures that automatically activate in the event of a malfunction. In addition, these types of reactors have better burnup characteristics, making them more efficient in fuel use and producing less waste, and are designed for a sixty year life compared with around thirty to forty years for generation 2 reactors.

Generation 4 reactor designs are currently being developed, with a view to deployment by around 2030. These reactors include molten salt reactors, supercritical water reactor, very high temperature reactor, liquid metal cooled fast breeder reactor, and gas cooled fast breeder reactors. The main feature of these types of reactor is that they substantially reduce the nuclear waste stream through their ability to use most of the input fuel and are more economic to operate.

traditional renewable energy sources

Traditional renewable energy technologies produce energy through harnessing natural processes, including from combusting solid biomass, such as wood, agricultural residues and animal waste, and harnessing hydro and geothermal power. In many parts of the APEC region, these sources of energy have been of long standing importance to communities that otherwise lack the financial resources and infrastructure to access commercial forms of energy, including electricity. These communities often live in rural areas far from large population zones. In these locations, energy derived from these sources is taken up primarily because it is affordable. Further detail on traditional renewable energy source is provided in appendix D.

new renewable energy sources

There is an increasing interest in new renewable energy technologies, for various reasons. These reasons include reducing pollution levels from the combustion of solid biomass fuels, thereby avoiding the adverse health impacts associated with solid biomass combustion, diversifying the energy mix, and providing a less greenhouse gas intensive form of energy than that derived from conventional sources. These technologies include advanced biomass combustion technologies, such as deriving electricity and heat from municipal waste combustion, biogas, hydropower, geothermal energy sources and solar and wind technologies.

There are a number of new renewable energy technologies that are currently in early stages of development, including hot rock geothermal power, wind, solar and tidal energy technologies (see appendix D for further details). These technologies produce energy without significant greenhouse gas emissions and hence do not contribute to the buildup of greenhouse gases in the earth's atmosphere. This is the major reason for international interest in new renewable energy technologies.

The cost competitiveness of new renewable energy technologies is dependent on its regional context and the type of technology being considered. In rural areas, where grid based electricity supply is not available, new renewable energy technologies can offer a viable and safe alternative to traditional biomass fuels. In addition, hydroelectric or geothermal energy may be cost competitive with alternative energy technologies in areas that have a strong hydroelectric or geothermal potential.

In well established energy markets, new renewable energy technologies are high cost energy options when compared with conventional energy sources, including coal, oil, gas, nuclear and hydroelectricity. The dependence of new renewable energy technologies on variable natural elements such as wind speed and solar radiation to achieve reliable production levels significantly increase energy production costs. Without further significant technological development to reduce costs, these technologies are unable to provide a cost effective alternative to conventional energy sources for baseload power generation in the short to medium term.

emission control in the electricity sector

There are several principal technologies designed to control emissions of particulates, carbon dioxide, sulfur dioxide and nitrous oxides from power generation plants (see appendix D for further details). Emissions of nitrous oxides can be abated or controlled by primary measures, such as the use of low nitrous oxide burners, staged combustion and natural gas afterburning to minimise the formation of nitrous oxides during combustion, or flue gas treatment technologies.

Advanced technologies for capturing and storing carbon dioxide are not yet proven on a commercial scale for adoption in electricity generation – so-called carbon capture and storage technologies (CCS). While technologies exist that are able to effectively capture carbon dioxide at the point of source, the storage of carbon dioxide is yet to be proven at the commercial scale.

Research expenditure in electricity generation technologies is generally seeking to develop or improve zero carbon dioxide emitting fossil fuel technologies. These technologies are designed to provide reductions in carbon dioxide emissions beyond what is achievable through increases in thermal efficiency. Much of this research is focused on refining IGCC technology at a commercial scale, and developing fuel cells, and carbon capture and storage technologies. Potential storage locations for carbon dioxide are deep geological formations that are estimated to have a storage potential of 2000 gigatonnes of carbon dioxide (http://en.wikipedia.org/wiki/Carbon_capture_and_storage).

The first CCS power plant is likely to be constructed in the United States through the FutureGen project that focuses on building a near zero emissions 275 megawatt coal fired plant that uses carbon capture and storage and is able to produce hydrogen as a fuel byproduct. The plant is expected to be on line by 2012 at a project cost of approximately US$870 million (http://en.wikipedia.org/wiki/FutureGen).

electricity generation costs

Energy security and environmental considerations are important factors in determining the technology choice for stationary energy supply in APEC economies. However, these factors are usually balanced against economic considerations. The weight placed on economic criteria in different regions varies, depending on regional differences in energy resource endowments and government policies related to the use of different energy sources.

In general, the costs of electricity generation are a function of the fuel cost, the capacity of the power generation plant, efficiency of the technology employed and the cost of financing. Government policy may also affect the price of electricity generation if taxes, such as carbon taxes, or subsidies are applied in the energy sector.

electricity generation costs of coal and gas fired power plants

A summary of capital and generation costs for a range of available electricity generation technologies is provided in table 5. These costs are from a range of sources and are representative costs from a variety of economies. Average thermal efficiencies for the technologies are also presented, as well as estimated emissions of carbon dioxide. More detailed cost information for electricity generation can be found in OECD-NEA and IEA (2005).

table 5 **estimated costs and thermal efficiencies of power generation plants**

	average efficiency % LHV	total plant capital cost US$/kW	power generation cost US¢/kWh	CO_2 emissions g/kWh
technology				
coal fired technologies				
pulverised coal systems				
subcritical pulverised coal	36	1095–1150	4.0–4.5	766–789
supercritical pulverised coal	45	950–1350	3.5–3.7	722
ultra supercritical pulverised coal	45	1160–1190	4.2–4.7	
fluidised bed technologies				
fluidised bed combustion	30–35	1000–600	3.3	717
pressurised fluidised bed combustion	39	1150–650		
other				
integrated gasification combined cycle (IGCC)	42–44	1100–600	3.9–5.0	710–750
integrated dewatered gasification combined cycle	42	2.3–4.0	810	
gas fired technologies				
gas simple cycle	30	300–600		
gas subcritical steam turbine	37			
gas supercritical steam turbine	40			
natural gas combined cycle (NGCC)	50	400–700	3.4–6.8	344–430

Source: USDOE (2001); APEC (2001); IEA (2002a, 2004); AGO (2004); DTI (2004).

The costs (other than fuel) and operational characteristics of new technologies are expected to improve over time. The cost of new technologies varies between economies and will be influenced by the availability, quality and price of fuel, and capital costs. For the newest technologies, capital costs are initially high but are expected to decline as more units are built. The maturity of the technology is also likely to influence regional cost differentials.

When compared with coal fired power generation plants generally, combined cycle gas turbines (NGCC) are in general cheaper to build per kilowatt of electricity output, quicker to construct, produce fewer harmful greenhouse gas emissions, offer a higher energy conversion efficiency, occupy less space, and have other advantages such as the ability to rapidly increase or decrease electricity production. Natural gas power generation plants also have an advantage because no sulfur or particulate control systems are required, nor are systems for the control of nitrogen oxides in many economies. However, they also have higher operating costs than coal fired plants, driven mainly by fuel costs.

6

energy efficiency and cleaner technologies in end use applications in the APEC stationary energy sector

It is increasingly recognised that improving energy efficiency and using cleaner technologies in end use applications in the APEC stationary energy sector can bring substantial net benefits to economies. For example, investments in energy efficiency in the industry, residential and commercial sectors can deliver positive net economic benefits, improve energy security through lower energy use, reduce environmental impacts (both local and global), and increase local manufacturing and trade opportunities (such as through harmonising performance standards).

In this chapter, the distribution of energy consumption across the main end use sectors in the APEC region is outlined, with some key differences in the pattern of energy consumption across these sectors, between higher and lower income APEC economies, highlighted. Then technology options for improving the energy efficiency of end use sectors are discussed. The material presented is drawn from a range of sources that describe currently available technologies that could be deployed in any region to improve energy efficiency or make energy use in the end use sector more sustainable from an environmental perspective.

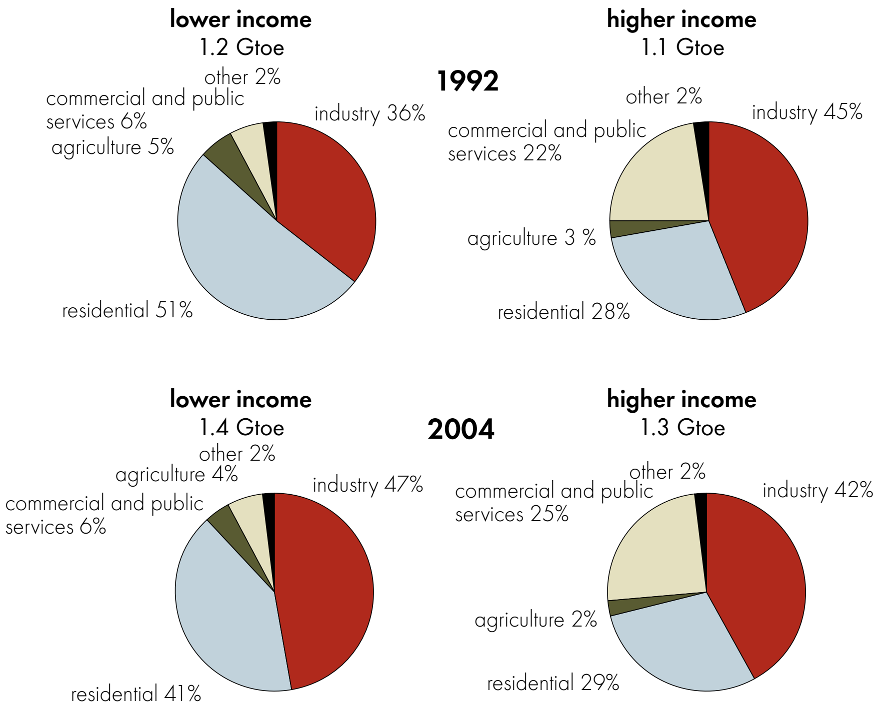
final energy consumption and energy intensity in the APEC stationary energy sector

stationary energy consumption by sector in APEC economies

In the APEC region, energy consumption by end use sectors is dominated by industry (45 per cent), households (35 per cent) and the commercial services sector (15 per cent), which together accounted for 95 per cent of final energy consumption in the APEC region in 2004. However significant regional differences exist in this pattern of consumption across lower and higher income APEC economies (figure N). This is particularly the case for energy consumption in the residential and commercial sectors in lower income APEC economies, which represented 41 per cent and 6 per cent of final energy consumption respectively, compared with 29 per cent and 25 per cent in higher income APEC economies in 2004. These differences highlight the different stages of economic development of higher and lower income APEC economies.

There is also significant regional disparity between the growth in energy consumption in subsectors of final energy consumption between lower and higher income APEC economies. Whereas most growth in final energy consumption in lower income economies is occurring in the industry sector, in higher income APEC economies it is the residential and commercial sectors where energy consumption is growing fastest. For example, energy consumption by the industry sector in lower

fig N **APEC stationary final energy consumption, by sector**



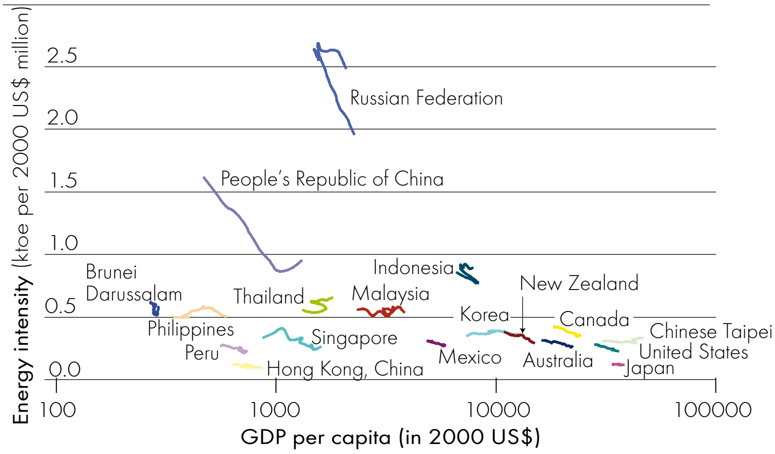
income APEC economies increased on average by 3.6 per cent a year between 1992 and 2004, with much of this growth occurring in the period 2000–04 (7.2 per cent a year). In contrast energy consumption growth in the industry sector in higher income APEC economies has been more moderate, growing on average at 0.8 per cent a year over the period 1992–2004. The current rapid industrialisation occurring in lower income APEC economies, together with the large share that energy consumption in the industry sector makes of final energy consumption, signals that energy efficiency improvements in the industry sector have the potential to make a significant contribution to slowing growth in APEC stationary energy use over the longer term.

energy intensity

Energy intensity is a frequently used metric that reflects the overall energy efficiency of an economy. Against the background of strong economic and energy growth throughout the APEC region, it is important to understand the key concept of energy intensity in each APEC economy. A brief discussion on the interpretation and use of this metric is provided in box 5.

The energy intensity of most APEC economies declined substantially over the period 1992–2004, and was strongly connected with rising incomes. Driving the decline in energy intensity in APEC economies were improvements in energy efficiency of industries, and structural shifts toward less energy intensive industries (figure O).

fig O **energy intensity and income levels of APEC economies, 1992–2004**



China accounts for a very large share of global and APEC industrial production. While the energy intensity of the Chinese economy followed a downward trend over the period 1992–2004, in the latter years of the period, changes in the relative output of industrial subsectors were driving overall energy intensity higher in China. Despite this trend, there remains significant potential for further reduction in China's energy intensity over the longer term through the adoption of energy efficient technologies. For example, in several industries, including cement, aluminium

box 5 energy intensity measures and energy efficiency

Energy intensity indicators can be used as a basis for evaluating the relative strengths and weaknesses of respective energy efficiency policies, identifying improvement potentials, and developing reasonable policy objectives.

At the simplest level, energy intensity represents the amount of energy consumed per unit of output, and reflects the cost to an economy of the energy consumption required to earn a unit of gross national product. Although such comparisons are desirable and justified, in practice the difficulty of constructing truly comparable indicators will, in most cases, limit the analysis. These difficulties arise from inconsistencies in a range of factors that influence the measurement of energy efficiency indicators. For example, the differences in the economic structure, resource base, prevalent technologies, data measurement techniques, as well as geographic and climatic considerations make indicators problematic in their application. Various data and indicator adjustments can be used to overcome these difficulties, such as the denomination of common currency unit or standardisation of annual heating days (this can be further complicated with the use of district heating in some APEC economies).

Movements in energy intensity over time can be further disaggregated into an efficiency effect, which measures the change in intensity accounted for by changes in economywide energy efficiency, and structural effects, which account for changes in the energy intensity accounted for by changes in the structural composition of output in an economy. Any remaining changes not accounted for by efficiency and structural effects can be considered to be a residual effect.

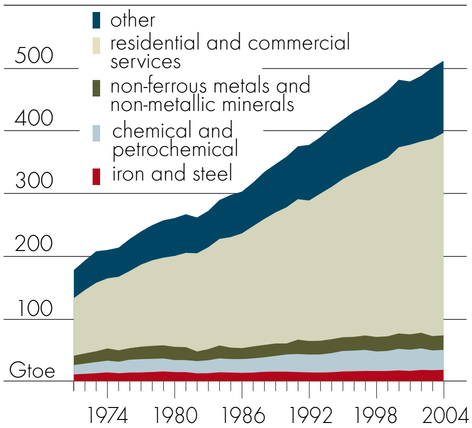
By isolating the importance of activity and structure, it is possible to estimate the impact of energy intensity effect on changes in energy consumption. The energy intensity effect is a better measure of efficiency than aggregate energy intensity (energy divided by activity) because it separates out the influence of structure and activity. The change in the energy intensity effect can be interpreted as an indicator of the 'change' in energy efficiency, the latter of which is only directly measurable at the greatest level of disaggregation.

and steel, there is still significant scope for energy efficiency improvements. For example, in primary steel production, there is a 20–40 per cent potential for these types of improvements based on existing technology (IEA 2006c).

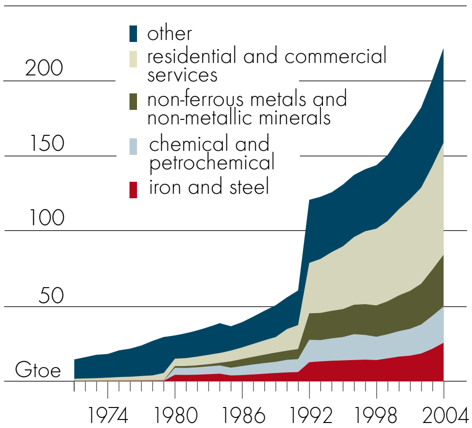
final electricity consumption by the end use sector in higher and lower income APEC economies

fig P **APEC final electricity consumption, by sector**

a. higher income



b. lower income excludes Russia before 1992



In 2004, the household and services sector of higher income APEC economies accounted for 56 per cent of final stationary energy consumption and 63 per cent of total final electricity consumption. In higher income APEC economies, total final electricity consumption in the residential and commercial services sector increased on average by 3.9 per cent a year between 1971 and 2004, much faster than growth in the chemicals and petroleum sector (2.3 per cent), iron and steel (1.6 per cent) and nonferrous metals and minerals sectors (1.3 per cent) (figure P, panel a).

In lower income APEC economies, households and the services sector accounted for 34 per cent of total final electricity consumption in 2004, an increase from 8.5 per cent in 1971 (figure P, panel b). The growth in electricity consumption by households and the services sector in lower income economies was much faster than in higher income economies, averaging nearly 22 per cent a year over the period 1971–91 and 6.9 per cent a year over the period 1992-2004. This fast growth was driven by increasing incomes, electrification schemes and increasing demand for household appliances.

technology options in end use applications of the stationary energy sector

The production of iron and steel, cement, aluminium as well as other primary metals and other building materials and chemical and petrochemical based products is characterised by heavy use of direct process heat. Heat is used in a variety of processes, including metals heating, melting and smelting, ore agglomeration, lime and cement calcining, clay and brick firing, and glass melting. Other industries are very dependent on electricity to drive large motors (metal mining operations grind ores to release metals) or to generate or purify chemicals or metals in electrocyclic cells. In addition, households and the commercial sector use significant quantities of electricity for lighting and for powering a range of appliances and heat for water and space heating purposes.

The development and diffusion of new technologies to improve the energy efficiency of heat and electricity use in the APEC stationary energy sector is important to the sustainable development of APEC economies. In lower income APEC economies, energy intensive industries are the primary focus of energy efficiency and conservation programs, particularly the iron and steel, aluminium, cement, and chemical and petrochemical industries. Improvements in the efficiency of energy use in the household and commercial services sector can also be significantly improved by the further diffusion of energy efficient technologies. Technology options to reduce energy consumption in the APEC stationary energy sector over the medium and longer term are detailed in appendix E.

iron and steel

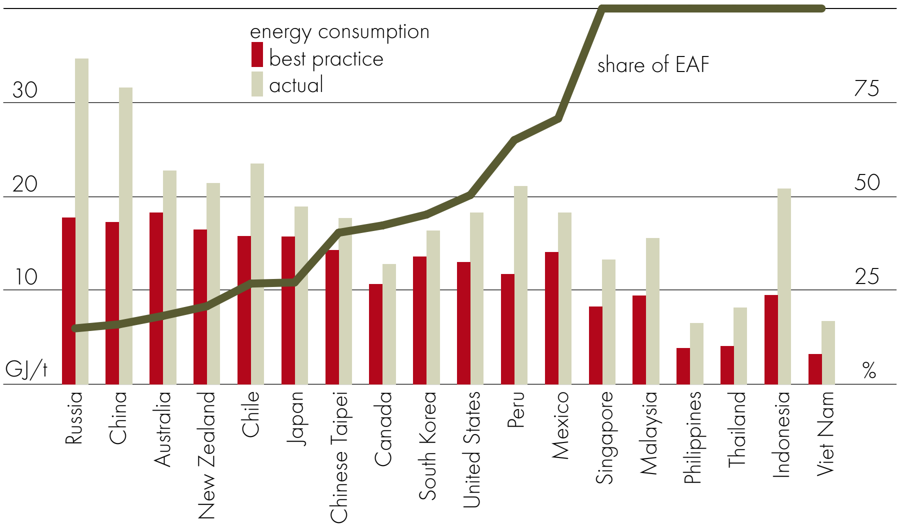
The iron and steel industry in APEC accounted for 13.5 per cent of total industry final electricity consumption in 2004. With production capacity expanding in China, the consumption of coal and coal products by the iron and steel industry has also increased. China accounted for 70 per cent of APEC coal consumption in the iron and steel industry in 2004, compared with 10 per cent in 1971.

The energy intensity of steel production in each APEC economy is largely determined by the share of steel produced by blast furnace based integrated steel mills and the iron feedstock used in electric arc furnaces in each economy. The major fuel in the integrated iron and steel making process is metallurgical coal, which is used in blast furnaces to produce iron. Blast furnace iron and steel production is in general a more energy intensive process than electric arc furnace steel production.

Blast furnace production is expected to continue to be the dominant production process within the region in the medium term. The highest energy efficiencies are recorded in economies, such as Japan and the Republic of Korea, where the steel industry is based around large scale, modern technology and where high energy costs and stringent environmental standards have encouraged steel producers to make energy saving investments. The lowest energy efficiencies are recorded in the Russian Federation, China and Indonesia, where a larger share of production is undertaken in older, smaller scale furnaces and where low energy costs have reduced incentives for steel makers to invest in energy saving technologies (figure Q).

Electric arc furnaces use scrap steel and are favoured for their flexibility in output and lower construction lead times than those of larger blast furnaces and are less energy intensive than blast furnace operations. Within APEC, electric arc furnaces are the dominant steel production method in Indonesia, Malaysia, Mexico, Peru, the Philippines, Singapore, Thailand, the United States and Viet Nam. According to

fig Q **energy efficiency of iron and steel production in APEC, 2002**



APERC (2000b), for the period 1980–94, the iron and steel sectors in a majority of APEC economies reduced their energy intensity. In 2005, electric arc furnaces contributed 27 per cent of APEC steel production.

The increasing use of electric arc furnaces for steel production has been beneficial from an energy efficiency and conservation perspective, but it is not typically suited to large scale applications. In economies other than the United States, the high share of steel produced by electric arc furnaces results from the large scale and high capital costs of integrated steel mills, which required these economies to pursue alternative steel production routes. The specific routes chosen in these economies were influenced largely by their endowments of other steel making inputs.

In the APEC region, the iron and steel industry currently uses a wide variety of technologies with a diverse range of energy consumption patterns. There are substantial differences between industry best practice benchmarks and the current production processes used in a number of APEC economies. Significant variation in the energy consumption of integrated steel mills is indicative of the large potential energy savings that modern mills have made through process improvements designed to optimise the purchased energy requirement of their operations. The development and accelerated diffusion of new technologies in the steel sector has the potential to significantly reduce growth in energy consumption in APEC economies as well as in greenhouse gas emissions. The uptake of new technology in the iron and steel industry could halve the growth in energy consumption for the period 2002–30 (Heaney et al. 2005).

There are a number of studies that have identified best practice opportunities and have quantified the magnitude of the R&D that is needed for the development of new technologies in the industry. Figure R shows the potential opportunities for energy savings for every unit of steel produced relative to current actual use in the United States (Energetics 2005).

The total opportunity for energy savings in figure R is estimated at 5.1 MBtu per ton of steel and was taken as the difference between current actual energy use (16.5 MBtu per ton) and the practical energy requirement (11.4 Mbtu per ton). The opportunity consists of two elements:

» best practices – state of the art technologies, processes and practices that are available today.

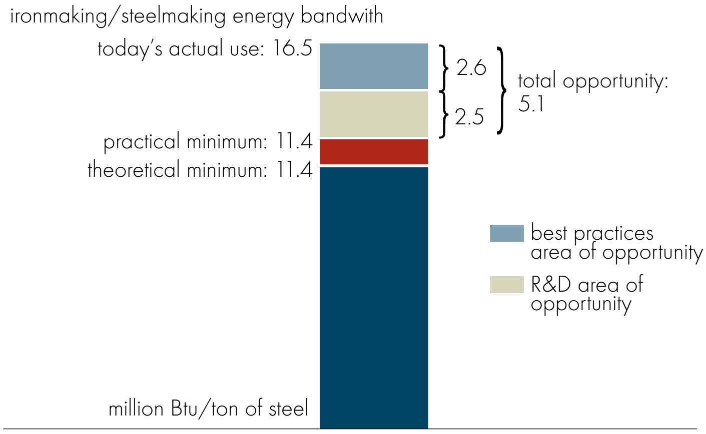
» **research and development opportunities** – new technologies, processes and practices that are under development or have been developed but require more effort in order to become more commercially viable.

There are many energy saving measures that steel mills could adopt to improve energy efficiency and environmental performance. Research and development in the steel industry focuses on the following areas:

- development of processes for raw material flexibility
- improvements in purity, cleanliness and homogeneity through refining and solidification processes
- synchronisation, continuation and integration of processing steps
- unification and simplification of processing steps
- system integration by automation and artificial intelligence (AI) control
- waste recycling

These process improvements have primarily involved the collection and reuse of hot waste gases from the blast furnace, the basic oxygen furnace and the coke ovens; partial substitution of coke with other fuels, such as pulverised coal and oil, in blast furnace and the development of better systems to control the fuel mix and

fig R **potential energy savings from adoption of industry best practice and research and development of new technologies**



operating conditions within the blast furnace. For example, in 2003, the industry in Japan completed the SCOPE 21 project – a 'super coke oven for productivity and environment' enhancement in the 21st Century. The project developed coke oven processes to improve energy efficiency and reduce environmental impacts. In 2006, Nippon Steel Corporation started construction of a new coke oven that uses this technology at its Oita Works. Other innovative R&D programs are also being carried out. These include development of technology for producing hydrogen by reforming coke oven gas and basic technology for creating ultrafine grained steel, as well as R&D aimed at making effective use of steel slag in marine areas.

aluminium

The APEC region contains five main primary aluminium producing economies, China, the United States, Canada, the Russian Federation and Australia. Together these economies account for a substantial portion of global aluminium production. A key determinant of energy efficiency improvements in the aluminium industry in these economies is not technology advancement but an increase in the share of scrap aluminium in production. Primary aluminium production is about twenty times as energy intensive as recyling (IEA 2006c).

The main energy use in aluminium production is related to the electricity used in the electrochemical conversion of alumina into aluminium. This conversion process typically requires 50–55 gigajoules of electricity per tonne of aluminium metal produced in the Hall-Heroult process, or around 60 gigajoules in the Soderburg process. This compares with a theoretical minimum energy requirement of 20 gigajoules per tonne of metal produced (IEA 2006c).

The difference in efficiency between the best and worst plants is approximately 20 per cent and reflects the different cell types used and to the size of the smelters, which is generally related to the age of the plants. The global average performance is 15 268 kWh per tonne of aluminium (IEA 2006c).

Refining bauxite to produce alumina, the main feedstock for aluminium production, also requires substantial quantities of energy. Much of the energy used is in the form of steam for refining, and heat for calcining alumina once refined. As is the case with aluminium there is significant potential for further improvements to the efficiency of alumina refineries. For example, in Australian plants, 11 gigajoules of energy is required per tonne of alumina produced. Improved heat integration and more efficient combined heat and power plants could reduce this requirement to around 9.5 gigajoules per tonne of alumina produced (IEA 2006c).

The technology used for aluminium production has been in existence since 1886. A number of technological breakthroughs have dramatically altered the energy efficiency and environmental performance of the industry. The global aluminium industry continues to adjust its production processes in response to increased input costs, environmental performance requirements and market pressures to seek new opportunities for reducing energy consumption and increasing productivity. For example, a number of initiatives that can be taken in the short term by industry in terms of improving environmental performance and reducing energy intensity include:

- adoption and benchmarking of environmental standards
- minimisation of perfluorocarbon emissions during the smelting process
- research and potential technology development for the management and recovery of components of bauxite residues, a byproduct of alumina that contains trace amounts of heavy metals
- development of technology and processing options to allow the more efficient use of low grade bauxite reserves in response to the global decline in high grade bauxite reserves
- promotion of benchmarking and the implementation of best practice processes for the management of perfluorocarbon emissions
- benchmarking and promotion of best practice on recycling, including assessment of use of recycled products for long term applications

box 6 aluminium taskforce AP6: management of perfluorocarbon emissions partners – United States, China and Australia

Key environmental concerns of the industry include greenhouse gas emissions, particularly during the smelting process, production of solid wastes such as red mud, and other gaseous and particulate emissions.

Perfluorocarbons, known as PFCs, form in the aluminium smelting process during brief imbalances of conditions within the smelter pot known as 'anode effects'. PFCs are more potent global warming gases than carbon dioxide and have long atmospheric lifetimes. The AP6 has identified that there is an excellent opportunity to further reduce anode effects and therefore PFC emissions through disseminating and deploying the highest standard of work practices appropriate to the smelting operation.

Source: APPCDC (2006); www.asiapacificpartnership.org

» development of an internet based technology provider register to allow industry and governments access to the best available technology.

In addition, AP6 members account for approximately 37 per cent of the world's aluminium production. Partners are involved in all processes of the aluminium life cycle, from bauxite mining and alumina production to smelting and aluminium recycling. Under the APPCDC, an aluminium taskforce has been established to explore the potential opportunities for increased energy efficiency and reduction in carbon emissions (box 6).

Other developments that are likely to be important in reducing energy consumption in the aluminium industry include, in the short run, the use of inert cathodes and anodes, and, in the longer run, redesigning the electrolysis process to use aluminium chloride or carbothermic processes. Individual companies are continuing research and development in these technologies.

cement

The production process for cement is energy intensive, with the production of cement clinker from limestone and chalk being the main energy consuming process in the production process. Energy represents 20–40 per cent of total production costs. A focus on achieving energy efficiency improvements in the cement sector has the potential for substantial net benefits, especially in developing countries. For example, world cement production grew by 237 per cent over the period 1970–2004, rising from 594 million tonnes to 2000 million tonnes, with the vast majority of the growth occurring in developing economies. The main driver of the growth in cement production is activity in the building and construction industry in these economies.

Some progress has been made in recent years in improving the energy efficiency of production processes for cement production. For example, according to APERC, for the period 1981–1995, energy intensity in the cement industry declined in the following APEC economies: Chile (average reduction of 3.8 per cent a year); Philippines (2.8 per cent); Republic of Korea (2.7 per cent); and Australia (2.6 per cent). However, most APEC economies are approaching best practice levels, consistent with the introduction of the dry process (especially NSP kilns) and other energy efficient technologies and practices.

According to APERC, the electricity intensity of cement production in comparison to energy intensity has remained fairly constant in APEC economies over the period 1980–1995 (APERC 2003a). The difference in the trend paths of the two indicators is dependent on the level of production in each APEC economy. Despite this there are opportunities for further advancement in the energy efficiency of production processes for cement production, especially in some developing APEC economies.

Technology utilised in the cement industry in developing economies (for example, China) differs greatly from industry best practice and is in general less energy efficient than technologies deployed in developed economies. For example, in China there is potential for energy efficiency improvements to be made by the industry, as it currently consumes 8–10 gigajoules of energy per tonne of cement annually in comparison with industry best practice energy consumption of 4–5 gigajoules per tonne of cement.

The greatest opportunity for energy savings in APECwide cement production is in the wider adoption of large scale rotary dry kiln technologies in developing APEC economies, which are around 30 per cent more energy efficient than wet kiln processes. For example, 55 per cent of cement kiln capacity in China is small scale vertical kilns, while 78 per cent of cement kilns in Russia use wet kiln processes. Fluidised bed kiln technologies may be deployed over the longer term that could drive energy consumption for cement consumption closer to the theoretical minimum energy use of 1.8–2.0 gigajoules per tonne of cement clinker (ABARE 2006).

Global greenhouse gas emissions from the cement industry have reached 2.2 billion tonnes of carbon dioxide, representing approximately 5 per cent of anthropogenic emissions. A possible route to reducing greenhouse gas emissions in the sector is to increase the use of biomass fuels in the sector. For example, in the United States the cement industry uses around 41 per cent of all waste transport vehicle tyres in combustion processes (IEA 2006c). Further reductions in carbon dioxide emissions are also possible by reducing the clinker proportion in cement. Clinker production is associated with significant process emissions that are not related to energy use. Possible substitutes for clinker include fly ash, blast furnace slag, synthetic slag, water glass and gypsum. The change to the clinker proportion in cement changes the strength characteristics of concrete mixes, and hence cement types need to be tailored to their final use.

Other options available to reduce carbon dioxide emissions in the cement industry include using waste heat from production processes for electricity generation, using dry processing technologies through preheater installation, and using advanced grinding technologies.

petroleum refineries and the chemical industry

The chemical and petrochemical industry is a significant industrial user of crude oil and natural gas in APEC. In 2004 this sector accounted for 19 per cent of APEC final industrial energy consumption. While most of the energy feedstock in this industry is locked into final products, such as plastics, solvents, ammonia and methanol, the embodied carbon emissions in these products can be released into the atmosphere later in their life cycle through incineration in the waste stream or direct combustion, as is the case in the transport sector.

While there are many thousands of petrochemical products produced, there are only a few products that require significant energy in their production. For example petroleum refining plants use crude oil as their primary feedstock and produce a range of products such as ethylene, propylene, aromatics and methanol, which are further processed into polymers, solvents and resins. In producing these products, large amounts of heat are used by distillation columns (for product separation) and other high temperature processes such as chlorine production, but also for pumps and other auxiliary processes.

Energy use by the petroleum industry is affected by many factors, including differences in crude oil characterisation, the type of petroleum product being generated, the technology used in distillation and cracking and general practices (Nyboer and Rivers 2002). For example, in a benchmarking study of refineries in Canada, it was shown that the energy efficiency of sixteen refineries varied significantly, ranging from a Solomon Energy Intensity Index (a widely used benchmark for measuring energy efficiency in the petroleum refining sector) of 73 to 118.

There are some indications that the energy efficiency of petroleum refineries is steadily improving. For example, energy efficiency of plants in Canada have shown steady improvement since 1990 through improvements in review of processes, installation of new heat recovery systems, improving, upgrading and maintaining practices and running onsite assessments or audits of energy performance (Nyboer and Rivers 2002). Potential for energy efficiency in this sector is further demonstrated in the British Petroleum analysis of its own refineries between 2001 and 2005, which shows a reduction in the Solomon Energy Intensity Index from 100 to 95.3 (www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/E/ES_new2005_energy_efficiency.pdf).

Another major output of the chemical and petrochemical industry is fertiliser from ammonia, which uses predominantly a natural gas feedstock for its production, but can be produced through using coal gasification or partial oxidation of oil products. The natural gas route to fertiliser production accounts for the majority of world fertiliser plant capacity but fertiliser production based on coal gasification and partial oxidation of oil is used widely in China. This factor alone implies a significant potential for energy efficiency improvements in the production of ammonia. For example, coal and oil based processes use 1.7 and 1.3 times more energy than a gas based process respectively (IEA 2006c).

Similar improvements in energy efficiency have been experienced in the chemicals industry. Catalysts lower the activation energy required for a reaction to complete and are used to produce most chemicals. There has been enormous progress in understanding the underlying molecular mechanisms, which is facilitating the development of new catalyst systems that has allowed for increased energy efficiency in chemical processes.

There are number of new process technologies that could be used by the petroleum refining industry to reduce operating costs, improve energy efficiency and limit capital outlays. For example, upgrading processes to minimise vacuum distillation and thermal cracking, not only improve energy efficiency but also lead directly to the production of (more valuable) lighter sweeter products (MK Jaccard & Associates 2004). Also a split tower arrangement is a type of atmospheric distillation where a high pressure tower and lower pressure condenser is used as a source of heat for other operations in the unit, such as the low pressure tower reboiler, reducing the overall energy consumption of the distillation process (MK Jaccard & Associates 2004).

Separation in the chemicals industry is a very energy intensive process, using approximately 40 per cent of all energy used in the industry (IEA 2006c). Technologies currently used in this process include distillation, fractionation and extraction. A less energy intensive means to chemical separation could be achieved through the use of membranes. Several processes exist, including microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrodialysis, gas separation and pervaporation. Energy savings from the use of membranes vary depending on application but could amount to between 20 and 60 per cent (IEA 2006c).

Membranes were first used to recover hydrogen in ammonia plants about twenty years ago. Today, many membrane based separation processes are being increasingly deployed in the food processing, chemicals, paper, petroleum refining and metals. For example, pervaporation is being increasingly used in the chemicals industry to split azeotropes. However, the industry remains small, with too few suitable membranes for the many chemical separation processes required. The adoption of membrane based separation processes will require further research to lower costs to be competitive with conventional separation processes. For example, membranes are being developed for the separation of specific gas mixtures but more research is required to improve their performance (IEA 2006c).

residential and commercial services

Energy efficiency and conservation in the residential and commercial services sector depend on the ability and willingness of consumers of energy to undertake particular actions given a myriad of influencing factors, including rising incomes; prices and charges (tariffs); the availability or accessibility of new technologies; and tradeoffs between efficiency and other factors, such as style, convenience and quality. Over the longer term, development of new technologies to improve energy efficiency and demand side management measures will be important in achieving an overall reduction in the energy intensity of these sectors.

Energy efficiency of buildings is highly affected by the individual users and available technologies. Other technologies help manage the load within the building—that is, they help manage user behaviour (IEA 2006c).

There are opportunities to increase energy efficiency in the residential and commercial sectors, including through improved building design, through further development of energy efficient appliance technologies for heating and cooling and other domestic and commercial purposes, and through improved management of building energy loads. Improvements in energy efficiency from developments in these areas can also defer the need for new investment in energy supply to a time when low emission sources are more widely available and at a lower cost.

There are a number of initiatives that can improve the energy efficiency of buildings and household appliances by incorporating better use of technology. These include:

- **appliances** (including office and consumer electronics and lighting) – delivering efficiency gains through advanced technology, efficiency standards and labelling, increasing consumer awareness, reducing appliance standby power
- **buildings** – increasing energy efficiency through improved regulatory processes, upgrading energy efficiency features of existing buildings and showcasing environmental best practice in new buildings
- **financing and contracting** – developing and demonstrating successful models of innovative approaches for overcoming barriers to the financing of, and contracting for, energy efficiency.

technologies affecting energy consumption in buildings

Improvements in existing technologies can improve energy efficiency in households and the commercial services sector and reduce carbon emissions. Most of the key technologies are already available and are economically viable on a lifecycle cost basis.

table 6 **technologies affecting energy consumption in buildings**

technology	technology status
building envelope	
windows	mature
insulation	mature
passive solar design	mature
natural ventilation	mature
lighting	developing
heating, cooling, ventilation	
conventional oil, gas and electric heaters	mature
advanced heating systems	
heat pumps	developing
active solar	developing
district heating and cooling	developing
thermal energy storage	developing
wood heating	mature
air conditioners	mature
mechanical ventilation	mature
wet appliances	
clothes driers	mature
dish washers	mature
cooking	mature
domestic hot water (conventional)	mature
solar hot water heating	mature
consumer products	
televisions	developing
computers and printers	mature
energy management system and controls	
meters and metering	developing

Source: Based on IEA (2006c).

The main areas where energy efficiency improvements may be made in buildings is provided in table 6. Of these areas, significant gains in energy efficiency can be made in the areas of lighting, heating and cooling and in improvements in household appliance technologies.

Energy efficiency in lighting is likely to continue to improve with the greater diffusion of compact fluorescent lamps across the APEC region, and over the longer term with the further development and refinement of solid state lighting technologies. Solid state lighting is created from light emitting diodes, rather than electrical filaments or gas. For example, lighting efficiency is estimated to increase by a factor of ten by 2025 in the United States. If solid state lighting achieves its price and performance targets over the next two decades, this will remove the need for more than 30 per cent of the estimated lighting energy consumption in 2025.

Combined heating and cooling contributes to a significant share of global household energy demand, with the share ranging between 40 and 60 per cent of total residential energy use in developed economies. In most developed economies the majority of heating requirements are currently provided through natural gas or electric resistance furnaces and boilers.

Emerging technologies, including efficient air sourced and ground sourced heat pumps and solar hydronic heating systems, are also beginning to contribute to residential heating (and cooling) requirements. In transition economies and some European regions, extensive district heating networks provide the majority of residential heating. In developing economies, oil based and wood fires also contribute to a significant share of heating demand.

Other developments in household appliance technology that may affect energy use by households include:

» emerging television technologies, such as organic light emitting diodes, that will offer large screen televisions using about as much energy as today's 34 cm portable televisions
» reducing or eliminating standby energy use through improved design combined with small solar cells and batteries
» improving efficiency of computers, with laptops now consuming less than 20 watts, compared with conventional computers that use over 100 watts
» making ongoing efficiency improvements in whitegoods, such as clothes dryers that use domestic hot water (sourced mostly from solar) as a heat source, or high efficiency heat pump technology combined with heat recovery
» improving building thermal performance and cooling technology efficiency and so reducing air conditioning energy requirements.

Developments in intelligent systems for homes that automate the process of managing the household energy load seem likely to provide the capacity to optimise the energy use of appliances. These systems will be able to manage energy use by equipment through identifying faults, and educating users in the energy consumption patterns of appliances. Flexible systems that automate the management of household energy loads can be retrofitted to homes and equipment and have the potential to reduce energy consumption.

7

barriers to investment in energy technology R&D, adoption and transfer

As noted earlier, energy security and sustainable development have become key issues for the APEC forum in recent years. The APEC Energy Security Initiative and other relevant energy policy arrangements in the APEC region were outlined in chapter 4. In chapters 5 and 6, information was presented on current and emerging energy efficiency and cleaner technologies in the APEC stationary energy sector. The development and deployment of such technologies is critical in achieving long term energy policy objectives in the APEC region.

In the remainder of this report, several key economic aspects of energy technology R&D, adoption and transfer to achieve adequate, affordable, reliable and cleaner energy in the APEC region are examined. A broad theme covered in this chapter is barriers to investment in the development and deployment of technologies, with a focus on the stationary energy sector.

energy technologies

Investment in technology R&D, adoption and transfer is critical to the long term energy outlook through addressing major energy security concerns and achieving sustainable development objectives. Technology R&D, adoption and transfer activities are relevant to both the supply side and demand side of energy markets and include, for example:

» **energy efficiency technologies** – new technologies may aim to reduce energy consumption in the economy by increasing the efficiency of energy production and use.

» **cleaner energy technologies** – technology development and deployment is important for the further development of renewable and other cleaner energy sources, including options to capture emissions such as flue gas desulfurisation (FGD) units to reduce sulfur dioxide emissions in coal fired electricity generation and carbon capture and storage (CCS).

» **energy exploration and production technologies** – new technologies facilitate energy exploration and production for both conventional and nonconventional sources. New environmental technologies are important for the upstream industry by allowing energy exploration and production activity to be undertaken in new areas while managing environmental impacts.

» **energy processing technologies** – alternative processing technologies, such as gas to liquids and coal to liquids plants, increase the flexibility of markets to adapt fuel types to different end uses.

» **energy substitution or switching technologies** – new technologies may increase the flexibility of energy markets to adjust to supply disruptions.

R&D activity, and the associated adoption and transfer of new technologies, is a key mechanism to increase the efficiency, diversity and environmental sustainability of energy markets.

The remainder of this chapter is focused on issues relating to technology R&D, adoption and transfer in the APEC region, with a focus on energy efficiency and cleaner technologies in the stationary energy sector. ABARE has undertaken several studies in recent years that have examined the role of technology in economic development and climate change (see, for example, Matysek et al. 2005, 2006; Fisher et al. 2006) – the rest of this chapter and the policy discussion in chapter 8 draw on these studies.

investment in energy technology research and development

Research and development (R&D) activity is defined by ABS (2002) as the systematic investigation or experimentation involving innovation or technical risk, the outcome of which is new knowledge, with or without a specific practical application, or new or improved products, processes, materials, devices or services – R&D activity extends to modifications to existing products/processes and ceases when work is no longer experimental.

ABS (2002) provides the following definitions for different categories of research and experimental development:

» **basic research** is experimental and theoretical work undertaken primarily to acquire new knowledge without a specific application in view – basic research may be pure basic research or strategic basic research.

- **pure basic research** is carried out without looking for long term benefits other than the advancement of knowledge.
- **strategic basic research** is directed into specified broad areas in the expectation of useful discoveries – strategic basic research provides the broad base of knowledge for the solution of recognised practical problems.
- **applied research** is original work undertaken in order to acquire new knowledge with a specific application in view – it is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving some specific and predetermined objectives.
- **experimental development** is systematic work, using existing knowledge gained from research or practical experience, for the purpose of creating new or improved products/processes.

It should be noted that, in this report, the terms industry investment and private investment are used interchangeably, although it is recognised that segments of the energy sector may be within the public sector – investment decisions by participants in the energy sector are assumed to be based on the assessed profitability of projects. Industry investment in R&D tends to be focused mainly on applied research and experimental development work where the commercial applications are more apparent – that is, areas that are substantially less risky in terms of capturing the benefits from their investment. Government tends to focus on basic and applied research, particularly where there may be broader industry and economywide benefits – that is, in areas where the private sector may not participate if the assessment is made that they would not capture adequate benefits, for example, through a patent or by maintaining secrecy about the knowledge.

Recent trends in private and public investment in energy R&D are briefly examined in Fisher et al. (2006). A key finding from Fisher et al. (2006) is that public spending on energy R&D has generally declined in the United States since the early 1980s, but has remained relatively stable in Japan. In addition, it is likely that private investment in energy R&D has declined over the past several decades.

investment in energy technology adoption and transfer

The decision by industry to invest in a new or enhanced technology is influenced by a range of factors that affect the risk adjusted profitability assessment, including cost competitiveness, government policies and the level of perceived risk. For example, investment in some of the more efficient technology options in fossil fuel based electricity generation, such as natural gas combined cycle (NGCC) power plants or integrated gasification combined cycle (IGCC) coal power plants, may occur based on the cost effectiveness of these options. Other advanced technologies, however, are only likely to become more cost competitive with traditional technologies under constraints on carbon dioxide emissions (Matysek et al. 2005). It may be noted that, when a new technology has been adopted, the costs and risks of the technology tend to fall through learning effects and associated efficiency improvements.

The development of new technologies tends to be undertaken in a relatively small number of developed economies. The timing and pattern of technology transfer to other economies varies, but this process of technology diffusion is often gradual (Heaney et al. 2005). Trade restrictions and information barriers tend to slow the diffusion of technology.

Matysek et al. (2005) note there are many important barriers to the diffusion of energy sector technologies that tend to impede or slow their adoption:

- intellectual property rights – concerns about intellectual property rights represent a key impediment to technology transfer. An example is restrictions on foreign ownership of energy sector assets, which reduces firms' control over the price received for its output and also its ability to protect its intellectual property. The response of foreign direct investment to stronger intellectual property right protection has been shown to increase as the level of industrialisation increases.
- macroeconomic conditions and trade restrictions – macroeconomic conditions greatly influence the potential for successful technology transfer. High inflation, incomplete pricing of materials, labour, energy and other inputs, as well as trade policies that disallow the free movement of capital all act as disincentives or impediments to transfer by significantly increasing the risk associated with investment and reducing credit availability. Risk also increases the discount rate, thereby affecting the attractiveness of investments.
- inadequate human capital – inadequate human capital may also hamper diffusion of new technologies. Lack of knowledge, skills and practical experience within the local labour force reduces productivity and impedes the effective implementation, operation and maintenance of technology. Since the overall level of productivity within an economy also influences the lending rate, this has important flow-on effects for credit availability. Capacity is also an issue in relation to labour having the skills required to undertake technological

needs assessments, benefit–cost analyses and environmental impact assessments, which are necessary in procuring, managing and financing technology.

» inadequate institutional capacities – institutional capacity is not only important from the perspective of providing adequate intellectual property rights protection, but also in relation to providing effective linkages between technology providers, users and developers. Institutional intermediaries are essential in ensuring coordination between various information sources, partnerships and networks to improve technology dissemination.

» inadequate supporting infrastructure – inadequate infrastructure can also impede investment, as projects can be dependent on external infrastructure, such as gas pipelines or electricity grids. If the infrastructure is unreliable or of poor quality then the project will be less likely to go ahead. Taxation regimes can deter investment if issues such as double taxation are not adequately dealt with. Market interventions such as tax and subsidy distortions also have the potential to alter the relative prices of energy and may distort incentives for switching to low carbon fuels.

Matysek et al. (2005) argue that any attempts to promote the diffusion of technologies will need to address such barriers using a comprehensive approach, while recognising that impediments will manifest themselves differently in different countries, and that identification and prioritisation of barriers needs to be country specific. Matysek et al. (2005) further argue that it is essential that technology adoption and diffusion be considered in the context of complex market factors such as the appropriateness of technologies for local environments, and potential energy and cost efficiencies with respect to alternatives.

Further issues relating to investment in technology R&D, adoption and transfer are discussed in Matysek et al. (2005) and Heaney et al. (2005).

More fundamentally, key barriers to investment in technology R&D, adoption and transfer that address long term energy challenges include limited economic incentives in energy markets to address energy security concerns (discussed further in, for example, Hogan et al. 2005), and limited or no economic incentives in energy markets to address the negative impact of energy supply and use on human health and the environment.

8

policy options for energy technology R&D, adoption and transfer in the APEC region

The development and deployment of energy efficiency and cleaner technologies in the APEC region is critical for addressing key energy security concerns and reducing major sources of air pollution, while also achieving reasonable rates of economic growth to achieve sustainable development goals. Governments of APEC economies have an important role in addressing various barriers to investment in technology R&D, adoption and transfer. In this chapter, the economic rationale for government intervention is briefly examined and policy options to encourage technology R&D, adoption and transfer are identified.

economic rationale for government intervention

sources of market failure

Failure of private markets to produce an optimal level of goods or services provides the economic rationale for considering government intervention. Two important sources of market failure for considering the role of government in encouraging technology R&D, adoption and transfer are the presence of externalities (spillover or third party effects) and imperfect information (including public good aspects).

externalities (spillover or third party effects)

Externalities occur as a byproduct or side effect of either the production or consumption of a good or service. A negative externality occurs when the actions of an individual – production or consumption decisions by a firm or consumer respectively – has a negative impact on others (third parties) where these impacts are not fully reflected in the price of the good or service. A positive externality arises when the actions of an individual has a positive unpriced impact on others.

An important issue for environmental assets is that prices do not exist or understate the services provided by the environment. As a consequence, the price mechanism fails to provide the appropriate signal to markets about the value of the asset. This causes a divergence between optimising private behaviour and optimising the community's wellbeing (utility or social welfare function). The negative environmental externalities associated with energy supply and use in APEC and other economies represent a major concern for policy makers.

imperfect information (public good aspects and asymmetric information)

Lack of information or asymmetric information may have implications for the efficient allocation of resources in the economy. Information may have public good characteristics depending mainly on the extent to which exclusion is not possible. Information is nonrival when consumption by one person does not interfere with consumption by others. A private firm (or consumer) is likely to invest in acquiring information provided the benefits of the information to the firm over time are assessed to exceed the costs and risks of the investment. For example, compared with the optimal outcome, there is likely to be a shortfall in private investment in additional information about the negative environmental impacts of energy supply and use owing to the lack of sufficient profit incentives for acquiring such information.

Asymmetric information occurs when information about the attribute of a good differs between buyers and sellers or between the generators of externalities and the affected third parties. There are two types of asymmetric information problems:

- **moral hazard** – the moral hazard problem occurs when the actions of one individual are not observable to others; for example, if a regulator cannot monitor actions, it will be difficult to enforce pollution abatement schemes.
- **adverse selection** – the adverse selection problem occurs when one individual cannot identify the type or character of others and, as a consequence, cannot assess the quality of a potential good or service; for example, this may be an issue for consumers assessing the reliability of ecoproducts.

key criteria for assessing policy options

Ideally, to provide an economic assessment of the role of government, policy options that address significant sources of market failure need to be identified and ranked, where feasible, according to the expected net economic benefits, including implementation costs. Only policy options that are expected to result in positive net economic benefits should be considered for implementation. From an economic perspective, the policy option that is expected to achieve the highest expected net economic benefits is the preferred policy option.

It should be noted that net economic benefits may be interpreted broadly to refer to a community's utility or social welfare function that represents a measure of well-being and may include economic, social and environmental factors. Importantly, some aspects of the assessment, such as equity issues and environmental values, rely on the subjective judgment of policy makers.

Fisher et al. (2006) argue that policy frameworks for addressing climate change in a manner consistent with economic growth and development should adhere to three fundamental principles – environmental effectiveness, economic efficiency and equity:

- environmental effectiveness – an environmentally effective policy must involve all major emitters to ensure that an appropriate environmental target can be achieved. Excluding any major emitters undermines the environmental effectiveness of abatement actions by reducing the potential pool of abatement options and increasing the burden on participating countries to achieve a given environmental goal. By encouraging the development and deployment of energy efficiency and cleaner technologies, particularly in large economies such as the United States and China, the APEC forum would reduce the likelihood of free riders gaining a competitive advantage and thereby inducing movement of emission intensive industries to economies that are making little or no attempt to reduce emissions themselves.
- economic efficiency – economically efficient climate policies meet a given environmental objective at lowest cost. Technology will play a key role in achieving the most cost effective outcome.
- equity – since the climate change problem transcends national boundaries, it requires an international response framework that is perceived to be fair. As such, the strategy needs to be consistent with sustainable economic development and needs to recognise that energy consumption in developing economies will need to grow over time to facilitate economic growth and development.

broad options for reducing long term energy consumption and/or emissions

There are several broad options that may be considered in reducing long term energy consumption and emissions:

- **improve the operation of the energy market (allocative efficiency improvements)** – remove distortions that encourage excessive energy consumption or limit access to alternative technologies. For example, removing or substantially reducing energy subsidies has the potential to significantly reduce future growth in long term energy consumption in the APEC region and, as a byproduct, emissions are also reduced (see IEA 2006b for further information on energy subsidies). More generally, achieving greater efficiencies in the operation of energy markets is likely to facilitate investment in energy technology R&D, adoption and transfer.
- **adopt more energy efficient technologies (technical efficiency improvements)** – energy efficiency improvements reduce future growth in energy consumption and, as a byproduct, emissions are also reduced. Energy efficiency improvements may be achieved in the conversion and end use sectors of the energy market. In the electricity sector, for example, increases in the efficiency of existing fossil fuel based electricity generation technologies or the development of more efficient technologies can result in a reduction in greenhouse gas emissions as less fuel is used per unit of electricity generated (Matysek et al. 2005).
- **fuel switching to reduce the emissions intensity of energy production and consumption** – switching to less emissions intensive fuel options will reduce future growth in emissions. For example, use of thermal coal with relatively low sulfur content reduces emissions of sulfur dioxide in coal fired electricity generation. In addition, switching to less carbon intensive fuels such as natural gas and renewable energy will reduce future growth in carbon dioxide emissions from the electricity sector.
- **emissions sequestration** – investing in technologies that capture emissions directly during the fuel combustion process and manage the disposal and/or reuse of the pollutants will reduce future growth in emissions from the energy market. For example, the capture and storage of carbon dioxide emissions from power plants represents an option that could potentially result in near zero carbon dioxide emissions from the burning of fossil fuels in the electricity sector (Matysek et al. 2005).

Overall, options that aim to reduce the future long term growth path of energy consumption have the flow-on benefit of reducing future growth in emissions. Other options aim to reduce directly the emissions from the energy sector – in these cases, future long term growth in energy consumption may be reduced to the extent that the cost of investing in fuel switching and emissions sequestration results in higher energy prices.

policy options to encourage technology R&D, adoption and transfer

A fundamental objective in energy technology R&D, adoption and transfer is to reduce the negative environmental impacts in energy supply and use – addressing energy security concerns through, for example, adopting technologies that achieve greater diversification in energy markets is also important.

Policy intervention is typically required to address significant sources of environmental damage (or negative environmental externalities). It should also be recognised that there is an important economic argument in support of policies to encourage technology R&D, adoption and transfer based on the presence of positive externalities or spillover effects from these activities:

- **technology R&D** – given the gap between the private and social returns of R&D and the positive spillovers associated with R&D, it is generally accepted that governments have a role to play in encouraging private sector R&D and also in providing public sector R&D in areas underrepresented in the private sector (Fisher et al. 2006).
- **technology adoption** – technology leaders are involved in the early adoption of new and enhanced technologies and, as a consequence, tend to incur additional costs and risks in these investments than would otherwise be the case. There tend to be positive spillover effects to technology followers as the costs and risks of technology adoption tend to be reduced somewhat through learning by doing effects.
- **technology transfer** – the transfer of new and enhanced technologies to other economies provides these technology follower economies with positive spillover effects associated with R&D costs avoided as well as the lower costs and risks of technology adoption. Although learning by doing mainly occurs in the technology leader economies (typically developed economies), there may be additional costs and risks in terms of adapting technologies to the circumstances of the technology follower economies (typically developing economies). As a consequence, there is likely to be the further process of learning by doing in the initial stages of transferring and adapting technologies to developing economies.

It is useful to distinguish between policy options that encourage R&D in new and enhanced technologies and policy options that encourage technology adoption and transfer. It should be noted, however, that policies that encourage investment in R&D tend to result in higher rates of technology adoption and transfer and, conversely, policies that encourage technology adoption and transfer provide economic incentives that tend to result in increased investment in R&D.

The benefits to regions of cooperating in technology R&D, adoption and transfer are highlighted in Fisher et al. (2006). In that study, cooperation within the framework of the AP6 in technology adoption and transfer is shown to reduce electricity consumption in the partnership region over the period 2010–50 to about 7 per cent below reference case levels in the partnership technology scenario, hence reducing the overall demand for energy and electricity supply infrastructure requirements over this period. The study also shows that global greenhouse gas emissions could be reduced by up to 17 per cent in 2050 compared with the reference case levels if partnership economies introduce carbon capture and storage technologies for electricity generation for coal and gas fired electricity generation.

encouraging research and development

There are several policy options that encourage R&D activity by providing greater economic incentives for industry investment in R&D (by reducing the costs and/or risks of the activity) and through direct support for public investment in R&D (including public–private partnership arrangements). Policy options to encourage investment in R&D include:

- intellectual property rights – intellectual property rights include patents, trademarks and copyright and are designed to provide a level of protection to the returns of the inventor in a good or service by restricting access to, or use of, the product for a specified period (Fisher et al. 2006). Strengthening property rights reduces the risks associated with private investment in R&D since private investors are more likely to obtain an adequate return from any discoveries.
- government support for R&D through grants, subsidies and tax incentives – even with intellectual property rights, private investment will be limited to R&D projects that are assessed to be profitable over time. There are likely to be R&D projects that are expected to result in net economic benefits over time, but that would not be undertaken in the private sector without additional support, owing to the lack of profit motive. Grants, subsidies or tax incentives (such as an accelerated rate of tax deduction) may encourage private investment in R&D by reducing the costs (and risks) of the activity. Governments may also provide direct support for the public provision of R&D. Prizes for the successful development of a technology may also encourage R&D among competing firms.

- » **R&D joint ventures and international collaboration** – joint ventures between private companies and/or public research organisations in one or more economies encourages R&D activity by reducing the costs and risks of R&D projects and facilitating information sharing. International collaboration between developed economies is particularly important for encouraging R&D and technology adoption. International collaboration between developed and developing economies is important in targeting R&D activity to adapt technologies to the specific circumstances of developing economies, for building R&D skills in developing economies as well as for technology transfer (discussed further below).

encouraging technology adoption and transfer

There are several policy options that encourage technology adoption and transfer by providing greater economic incentives for industry investment in new and enhanced technologies. Economic incentives may be introduced to encourage industry participants to identify the most cost effective option to meet a particular constraint (such as a performance standard or a tradable permit scheme). Other options introduce economic incentives for increased industry investment in technology adoption and transfer by reducing the costs and/or risks of the activity. International cooperation, such collaborative partnership arrangements, is an important component of any policy response. Policy options to encourage investment in technology adoption and transfer include:

- » **setting government technology and performance standards (including energy efficiency standards and labelling)** – this policy approach has the potential to increase the pace of technology diffusion in both developed and developing economies. Current applications in many economies, particularly developed economies, include fuel standards in the transport sector and restrictions on emissions of particulates and sulfur dioxide in electricity generation (see also Curtotti et al. 2006). Another example of setting government technology and performance standards is the mandate in California that, by 2030, 10 per cent of the cars sold by the seven largest automobile manufacturers in that state must be zero emission or near zero emission vehicles, such as electric and hybrid vehicles or conventional vehicles with certain additional emission controls (Fisher et al. 2006).
- » **government support for technology adoption through grants, subsidies and tax incentives** – these economic incentives may be justified to encourage initial industry investment in a new or enhanced technology given the posi-

tive flow-on benefits to others through learning by doing effects. An important aspect of this approach would be to ensure that the knowledge gained through learning by doing is transferred to subsequent users of the technology. Government support for demonstration projects is part of the process of encouraging the commercialisation of a new or enhanced technology (may be considered part of the development phase of the technological advance).

- **emissions trading scheme** – this approach has the potential to provide economic incentives to invest in new technologies to achieve a specified industry emissions constraint. An example is the sulfur dioxide emissions trading scheme established in the United States to limit future growth in sulfur dioxide emissions from electricity generation.
- **emissions tax** – a tax on emissions would encourage industry investment in low emissions technologies to the extent that it would be profitable to do so.
- **joint ventures and international collaboration** – joint ventures between private companies in one or more economies encourages technology adoption and transfer by reducing the costs and risks of these investment projects and facilitating information sharing. Technology transfer may be encouraged by strengthening intellectual property rights and providing institutional support and training in developing economies.

Policies to encourage technology R&D, adoption and transfer are discussed further in, for example, Fisher et al. 2006 and Matysek et al. 2006.

other economic aspects of energy technology development and deployment

The APEC forum has an important role in facilitating investment in technology development and deployment to address major energy security and sustainable development challenges in the region.

The policy response by APEC economies will be critical to support the development and deployment of more energy efficient and cleaner fuels and technologies in the region. Continued economic growth in the APEC region will be achieved at substantial environmental cost in the absence of an appropriate policy response with significant implications for regional energy security over the longer term. An important issue for APEC economies is the extent to which they are willing to adjust policy priorities with greater recognition of the longer term benefits of reducing environmental damage. Some broad policy approaches that may be considered in the short to medium term include, for example, reducing market impediments (for example, trade and investment liberalisation and reducing energy subsidies) and ensuring new energy infrastructure is compatible with future technological advances (to reduce the future cost of investment in energy efficiency and cleaner technologies).

In assessing future directions for policy cooperation in the APEC region, it may also be useful to consider the following economic aspects:

- clean coal technologies – coal is an important source of energy, accounting for 31 per cent of total primary energy consumption and 47 per cent of electricity generation in the APEC region in 2004. Global coal resources are relatively abundant, with a proved reserves to production ratio of around 155 years in 2005. Around 50 per cent of the world's proved reserves are located in the APEC region including, most notably, the United States (27 per cent), China (13 per cent) and Australia (9 per cent). Continued use of coal resources is likely to be important in sustaining economic growth over the next several decades, although the outlook depends critically on the cost competitiveness of alternative energy supply options. The development and deployment of clean coal technologies in the APEC region would result in significant future benefits by reducing the long term emissions growth associated with growing energy supply and use.
- nuclear based electricity generation – an option for reducing emissions from electricity generation is to switch to lower emission energy sources such as nuclear power. In assessing the extent to which APEC economies adopt policies to encourage the development and deployment of nuclear technology options, the benefits of reduced emissions need to be compared with the costs and risks associated with nuclear power. These risks include, for example, nuclear proliferation risks and waste disposal risks. Potential international positive spillover effects from nuclear technology transfer are reduced if these technologies are considered to be too high risk to be adopted in some economies or if some economies prefer not to use nuclear technology options because of the perceived relative costs and risks.
- risk assessments and adjustment paths – private investors are typically assumed to be risk averse, such that the riskier the investment in a new or enhanced energy technology, the less likely the investment will proceed (all else constant) – an important part of the learning by doing benefits associated with technology adoption and transfer is the lowering of risks. The policy assessment process of governments similarly needs to take into account the

various risks associated with policy options and outcomes (including a business as usual approach). The economic analysis of policy options may be based on the assumption of risk neutrality, whereby governments rank policy options according to expected outcomes. A risk averse approach would typically suggest that governments are averse to incurring costs with certainty (for example, to reduce emissions) compared with the relatively uncertain or risky future benefits. Under an environmentally precautionary approach (that is, using the precautionary principle), governments may be relatively more averse to the risk of future environmental damage – this would suggest that governments would encourage earlier investment in R&D, adoption and transfer in energy efficiency and cleaner technologies than would otherwise be the case. Contingency planning for adverse outcomes remains an important aspect of all policy approaches – this includes consideration of requirements for future investment in technologies to address (reduce or adapt to) damage associated with emissions from energy supply and use.

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conclusion

Through the Energy Security Initiative, the APEC forum has established a framework that enhances regional energy security and sustainable development prospects. However, there continue to be major policy challenges in achieving adequate, reliable, affordable and cleaner energy in APEC economies. Two important aspects of a cooperative policy response are improving the operation of energy markets and adopting more energy efficient and cleaner fuels and technologies.

improving the operation of energy markets

Reducing market impediments by facilitating regional energy trade and investment has the potential to significantly increase the efficiency of energy markets, providing both energy security and sustainable development benefits to the APEC region. For example, trade and investment liberalisation would improve access to new and enhanced energy technologies. In addition, more efficient energy markets would increase the flexibility of markets to adjust to temporary or sustained changes in supply and demand conditions (that is, adjustment costs would be reduced). A policy objective of energy self sufficiency within any given economy is not justified on energy security grounds since potential economic gains from trade would be lost under this policy approach – rather, the long term policy objective for governments in the APEC region is to ensure the provision of energy at least cost over time, given energy technologies and resource availability and taking into account environmental impacts and economic and other risks in the outlook.

improving energy efficiency and diversity

A major policy challenge is therefore to identify energy trade and investment barriers and assess in more detail options to address barriers to the development and deployment of more energy efficient and cleaner fuels and technologies. A further policy challenge for the APEC forum is to enhance regional economic prospects through sharing information about energy policy analysis and experience, including information on energy efficiency. Sharing energy policy experience is an effective means of developing policy ideas and superior policy strategies. Not all policy strategies will be easily transferable to other economies but many are, and improved understanding of what policies can succeed in different policy settings and environments is a valuable product of sharing policy experience.

A appendix

energy data for APEC economies

table 7 **fuel shares in total primary energy consumption, by APEC economy, 2004 a**

	coal	oil	gas	nuclear	renewables: hydro	renewables: geo-thermal	renewables: solar/ wind etc c	renewables: combustible renewables and waste	renewables: total
	%	%	%	%	%	%	%	%	%
United States	23.5	40.8	22.1	9.1	1.0	0.4	0.1	3.0	4.5
Canada	10.6	36.4	28.9	8.7	10.9	0.0	0.0	4.4	15.3
Hong Kong, China	39.7	49.1	10.8	0.0	0.0	0.0	0.0	0.3	0.3
Australia	42.7	32.0	19.6	0.0	1.2	0.0	0.1	4.3	5.6
Japan	21.8	47.8	13.2	13.8	1.5	0.6	0.1	1.2	3.4
Singapore	0.0	79.3	20.7	0.0	0.0	0.0	0.0	0.0	0.0
Chinese Taipei	35.9	44.0	8.5	9.9	0.5	0.0	0.0	1.1	1.7
New Zealand	10.7	39.9	19.6	0.0	13.2	11.5	0.2	5.0	29.9
Brunei Darussalam	0	27.1	72.2	0.0	0.0	0.0	0.0	0.7	0.7
Korea, Rep. of	23.5	47.6	11.9	16.0	0.2	0.0	0.0	0.8	1.0
Chile	13.0	39.9	24.3	0.0	7.3	0.0	0.0	15.5	22.8
Malaysia	10.1	48.0	36.1	0.0	0.9	0.0	0.0	4.9	5.8
Russian Federation	16.2	20.4	54.0	5.9	2.4	0.1	0.0	1.1	3.5
Mexico	4.3	58.1	26.4	1.4	1.3	3.4	0.0	5.0	9.8
Thailand	10.7	47.2	25.2	0.0	0.5	0.0	0.0	16.4	17.0
China, People's Rep. of	61.7	19.3	2.6	0.8	1.9	0.0	0.0	13.7	15.6
Peru	6.9	57.1	6.6	0.0	11.4	0.0	0.4	17.7	29.5
Philippines	12.2	37.7	4.5	0.0	1.7	20.0	0.0	23.9	45.6
Indonesia	12.8	37.0	19.4	0.0	0.5	3.3	0.0	27.1	30.8
Viet Nam	16.6	24.0	9.2	0.0	3.0	0.0	0.0	47.2	50.2
Papua New Guinea b	0	86.3	8.5	0.0	5.2	0.0	0.0	0.0	5.2
APEC	30.7	34.5	19.3	6.3	1.9	0.5	0.1	6.8	9.2
higher income	23.1	42.0	20.2	9.8	1.8	0.4	0.1	2.7	5.0
lower income	40.3	25.1	18.2	1.9	1.9	0.7	0.0	11.9	14.5
world	25.1	34.3	20.9	6.5	2.2	0.4	0.1	10.6	13.3

a Total primary energy consumption (TPEC) is also referred to as total primary energy supply. **b** Based on 2003 data. **c** Includes solar, wind, tide and wave energy.
Sources: IEA (2006); EGEDA (2006).

table 8 fuel shares in electricity generation, by APEC economy, 2004 a

	coal	oil	gas	nuclear	renewables: hydro	renewables: geo-thermal	renewables: solar/ wind etc c	renewables: combustible renewables and waste	renewables: total
	%	%	%	%	%	%	%	%	%
United States	50.4	3.4	17.6	19.6	6.5	0.4	0.4	1.7	9.0
Canada	17.2	3.6	5.4	15.1	57.0	0.0	0.2	1.5	58.7
Hong Kong, China	68.5	0.6	30.9	0.0	0.0	0.0	0.0	0.0	0.0
Australia	79.3	0.7	12.3	0.0	6.8	0.0	0.3	0.6	7.7
Japan	27.5	12.4	22.8	26.4	8.8	0.3	0.1	1.7	11.0
Singapore	0.0	31.2	68.8	0.0	0.0	0.0	0.0	0.0	0.0
Chinese Taipei	53.2	7.1	17.1	18.1	3.0	0.0	0.0	1.5	4.5
New Zealand	9.9	0.1	16.7	0.0	64.6	6.5	0.9	1.3	73.3
Brunei Darussalam	0.0	1.0	99.0	0.0	0.0	0.0	0.0	0.0	0.0
Korea, Rep. of	38.8	8.0	16.2	35.7	1.2	0.0	0.0	0.1	1.3
Chile	16.1	1.5	34.0	0.0	45.4	0.0	0.0	3.0	48.4
Malaysia	27.9	3.3	61.8	0.0	7.0	0.0	0.0	0.0	7.0
Russian Federation	17.3	2.7	45.3	15.6	18.9	0.0	0.0	0.2	19.1
Mexico	10.7	31.1	38.8	4.1	11.2	2.9	0.0	1.1	15.3
Thailand	15.9	6.2	71.0	0.0	4.8	0.0	0.0	2.2	7.0
China, People's Rep. of	77.9	3.3	0.4	2.3	16.1	0.0	0.0	0.1	16.2
Peru	3.8	15.1	8.2	0.0	72.3	0.0	0.0	0.7	72.9
Philippines	28.9	15.2	22.1	0.0	15.4	18.4	0.0	0.0	33.7
Indonesia	40.1	30.2	16.1	0.0	8.1	5.5	0.0	0.0	13.6
Viet Nam	15.3	3.7	42.7	0.0	38.4	0.0	0.0	0.0	38.4
Papua New Guinea b	0.0	48.0	15.0	0.0	35.0	2.0	0.0	0.0	37.0
APEC	46.9	5.5	18.0	14.7	13.2	0.4	0.2	1.1	14.9
higher income	43.9	5.2	17.5	20.1	11.2	0.3	0.3	1.5	13.4
lower income	52.3	5.9	18.8	5.3	16.7	0.6	0.0	0.3	17.6
world	39.8	6.7	19.6	15.7	16.1	0.3	0.5	1.3	18.2

a Based on electricity output in GWh. **b** Based on 2003 data. **c** Includes solar, wind, tide and wave energy.
Sources: IEA (2006); EGEDA (2006).

table 9 **fuel shares in total final energy consumption (TFEC), by APEC economy, 2004**

	coal	oil	gas	renewables: geo-thermal	renewables: solar/ wind etc b	renewables: combustible renewables and waste	renewables: total	electricity	heat
	%	%	%	%	%	%	%	%	%
United States	2.1	54.1	20.9	0.1	0.1	2.9	3.1	19.6	0.2
Canada	1.7	45.3	26.1	0.0	0.0	4.9	4.9	21.4	0.5
Hong Kong, China	0.0	64.8	5.1	0.0	0.0	0.5	0.5	29.6	0.0
Australia	4.5	50.7	16.0	0.0	0.1	5.6	5.7	23.1	0.0
Japan	7.6	60.3	7.5	0.1	0.2	0.7	0.9	23.5	0.2
Singapore	0.0	80.2	0.7	0.0	0.0	0.0	0.0	19.0	0.0
Chinese Taipei	11.1	60.3	2.8	0.0	0.0	0.0	0.0	25.8	0.0
New Zealand	6.5	49.7	14.3	2.5	0.0	5.1	7.6	21.8	0.0
Brunei Darussalam	0.0	69.4	0.0	0.0	0.0	2.2	2.2	28.3	0.0
Korea, Rep. of	5.2	60.4	10.1	0.0	0.0	1.0	1.0	20.2	3.0
Chile	3.4	43.5	16.5	0.0	0.0	18.0	18.0	18.6	0.0
Malaysia	2.6	59.1	16.8	0.0	0.0	4.4	4.4	17.2	0.0
Russian Federation	4.0	22.4	29.3	0.0	0.0	0.6	0.6	13.1	30.6
Mexico	1.2	64.7	13.4	0.0	0.1	6.8	6.9	13.8	0.0
Thailand	8.7	56.2	3.3	0.0	0.0	16.5	16.5	15.3	0.0
China, People's Rep. of	33.6	24.5	3.1	0.0	0.0	21.1	21.1	14.3	3.5
Peru	4.6	60.0	0.4	0.0	0.5	18.8	19.2	15.8	0.0
Philippines	4.3	50.8	0.0	0.0	0.0	30.9	30.9	14.0	0.0
Indonesia	6.3	40.3	11.9	0.0	0.0	35.0	35.0	6.6	0.0
Viet Nam	14.9	26.0	0.0	0.0	0.0	51.4	51.4	7.6	0.0
Papua New Guinea a	0.0	76.6	0.0	0.0	0.0	0.0	0.0	23.4	0.0
APEC	10.8	44.0	14.7	0.0	0.0	8.9	9.0	17.5	4.0
higher income	3.4	54.9	18.0	0.1	0.1	2.6	2.8	20.6	0.4
lower income	20.5	30.0	10.4	0.0	0.0	17.0	17.0	13.4	8.7
world	8.4	42.3	16.0	0.0	0.1	13.7	13.8	16.2	3.3

a Based on 2003 data. **b** Includes solar, wind, tide and wave energy.
Sources: IEA (2006); EGEDA (2006).

table 10 **total final energy consumption (TFEC) by end use activity and by APEC economy, 2004**

	industry	transport	agriculture	commercial and public services	residential	non-specified other energy use	non-energy use
	%	%	%	%	%	%	%
United States	18.8	39.9	1.1	12.5	16.6	0.9	10.2
Canada	27.9	27.6	1.8	15.4	15.6	0.0	11.8
Hong Kong, China	8.5	54.4	0.0	24.4	10.8	0.1	1.8
Australia	30.9	39.7	2.9	7.7	13.1	0.0	5.6
Japan	28.9	26.6	1.9	16.1	13.5	1.0	12.1
Singapore	8.5	36.6	0.0	7.2	4.3	0.0	43.4
Chinese Taipei	34.8	23.0	0.3	5.2	8.5	4.1	24.0
New Zealand	27.5	41.7	2.2	7.8	10.0	0.9	10.0
Brunei Darussalam	18.1	49.5	0.0	20.3	7.0	2.2	2.9
Korea, Rep. of	26.4	23.8	1.4	12.5	12.1	1.6	22.2
Chile	46.1	27.2	1.1	4.2	21.1	0.3	0.0
Malaysia	37.9	39.8	0.2	7.0	9.5	0.0	5.6
Russian Federation	29.9	22.3	2.3	4.8	31.7	2.7	6.3
Mexico	25.7	42.8	2.7	3.3	17.1	0.0	8.4
Thailand	33.3	33.4	5.5	4.8	15.1	0.1	7.8
China, People's Rep. of	41.3	10.0	3.9	3.8	31.0	1.3	8.7
Peru	28.9	32.4	4.9	2.4	29.7	0.0	1.8
Philippines	31.2	34.0	1.1	7.4	22.1	2.9	1.3
Indonesia	20.1	21.3	1.9	5.2	43.7	0.3	7.5
Viet Nam	20.3	15.9	1.4	3.4	58.6	0.0	0.4
Papua New Guinea	na	na	na	na	na	na	na
APEC **a**	27.9	27.8	2.1	9.2	22.0	1.0	9.9
higher income	22.1	35.7	1.3	12.9	15.4	0.7	11.7
lower income	35.4	17.5	3.2	4.2	30.7	1.4	7.5
world	26.9	25.8	2.2	7.8	26.4	1.8	8.9

a APEC total excludes Papua New Guinea. **na** Negligible/not available.
Source: IEA (2006).

table 11 fuel shares in final energy consumption (TFEC), by APEC economy, 2004 – industry

	coal	oil	gas	renewables: geo-thermal	renewables: solar/ wind etc b	renewables: combustible renewables and waste	renewables: total	electricity	heat
	%	%	%	%	%	%	%	%	%
United States	10.4	11.5	40.1	0.0	0.0	10.2	10.2	27.0	0.8
Canada	5.8	11.3	35.8	0.0	0.0	14.1	14.1	31.2	1.7
Hong Kong, China	0.0	60.0	2.2	0.0	0.0	0.0	0.0	38.0	0.0
Australia	13.8	13.5	28.0	0.0	0.0	11.1	11.1	33.6	0.0
Japan	26.0	28.1	10.6	0.0	0.0	2.3	2.3	33.1	0.0
Singapore	0.0	5.2	5.0	0.0	0.0	0.0	0.0	89.9	0.0
Chinese Taipei	31.1	25.4	2.9	0.0	0.0	0.0	0.0	40.6	0.0
New Zealand	19.1	10.0	15.1	7.7	0.0	16.8	24.5	31.4	0.0
Brunei Darussalam	0.0	82.7	0.0	0.0	0.0	0.0	0.0	17.3	0.0
Korea, Rep. of	18.1	20.8	10.4	0.0	0.0	3.0	3.0	40.2	7.6
Chile	7.2	24.0	30.8	0.0	0.0	10.5	10.5	27.5	0.0
Malaysia	6.8	36.3	33.7	0.0	0.0	0.5	0.5	22.8	0.0
Russian Federation	7.9	9.6	21.8	0.0	0.0	0.6	0.6	22.6	37.6
Mexico	4.7	21.7	37.6	0.0	0.0	3.8	3.8	32.2	0.0
Thailand	26.1	21.4	8.7	0.0	0.0	22.4	22.4	21.3	0.0
China, People's Rep. of	59.8	8.5	2.8	0.0	0.0	0.0	0.0	23.2	5.8
Peru	15.7	51.9	1.3	0.0	0.0	0.1	0.1	31.1	0.0
Philippines	11.9	23.7	0.0	0.0	0.0	49.1	49.1	15.3	0.0
Indonesia	31.3	28.3	20.5	0.0	0.0	7.2	7.2	12.7	0.0
Viet Nam	54.5	28.8	0.2	0.0	0.0	0.0	0.0	16.4	0.0
Papua New Guinea a	0.0	68.6	0.0	0.0	0.0	0.0	0.0	31.4	0.0
APEC	30.1	13.7	18.6	0.0	0.0	4.8	4.8	26.3	6.4
higher income	14.4	15.9	29.7	0.1	0.0	8.3	8.3	30.5	1.2
lower income	42.8	11.9	9.7	0.0	0.0	2.0	2.0	22.9	10.7
world	8.4	42.3	16.0	0.0	0.1	13.7	13.8	16.2	3.3

a Based on 2003 data. **b** Includes solar, wind, tide and wave energy.
Sources: IEA (2006); EGEDA (2006).

table 12 **fuel shares in final energy consumption (TFEC), by APEC economy, 2004 – agriculture**

	coal	oil	gas	renewables geo-thermal	renewables solar/ wind etc b	renewables combustible renewables and waste	renewables total	electricity	heat
	%	%	%	%	%	%	%	%	%
United States	3.4	96.4	0.0	0.0	0.0	0.2	0.2	0.0	0.0
Canada	0.0	63.5	12.6	0.0	0.0	0.0	0.0	23.9	0.0
Hong Kong, China	–	–	–	–	–	–	–	–	–
Australia	0.0	92.5	0.1	0.0	0.0	0.0	0.0	7.4	0.0
Japan	0.0	96.6	0.0	1.4	0.0	0.0	1.4	1.9	0.0
Singapore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Chinese Taipei	0.0	1.8	0.0	0.0	0.0	0.0	0.0	98.2	0.0
New Zealand	4.0	56.3	0.0	0.0	0.0	0.0	0.0	39.7	0.0
Brunei Darussalam	–	–	–	–	–	–	–	–	–
Korea, Rep. of	0.0	77.3	1.1	0.0	0.0	0.0	0.0	21.6	0.0
Chile	5.0	59.8	30.1	0.0	0.0	0.0	0.0	5.0	0.0
Malaysia	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russian Federation	1.1	44.9	4.9	0.0	0.0	1.2	1.2	15.9	31.9
Mexico	0.0	79.0	0.0	0.0	0.0	0.0	0.0	21.0	0.0
Thailand	0.0	99.4	0.0	0.0	0.0	0.0	0.0	0.5	0.0
China, People's Rep. of	31.8	50.9	0.0	0.0	0.0	0.0	0.0	17.3	0.0
Peru	0.9	58.3	0.0	0.0	0.0	25.4	25.4	15.4	0.0
Philippines	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indonesia	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Viet Nam	7.8	83.3	0.0	0.0	0.0	0.0	0.0	8.9	0.0
Papua New Guinea **a**	na	na	na	na	na	na	na	na	na
APEC	14.6	68.4	1.1	0.1	0.0	0.3	0.4	12.1	3.4
higher income	1.8	90.2	1.5	0.3	0.0	0.1	0.4	6.0	0.0
lower income	21.4	56.8	0.9	0.0	0.0	0.4	0.4	15.3	5.1
world	8.4	42.3	16.0	0.0	0.1	13.7	13.8	16.2	3.3

a Includes solar, wind, tide and wave energy. **na** Not available. – Negligible/not available.
Source: IEA (2006).

table 13 **fuel shares in final energy consumption (TFEC), by APEC economy, 2004 – commercial and public services**

	coal	oil	gas	renewables geo-thermal	renewables solar/ wind etc a	renewables combustible renewables and waste	renewables total	electricity	heat
	%	%	%	%	%	%	%	%	%
United States	1.2	8.9	35.9	0.2	0.0	0.7	0.9	52.7	0.3
Canada	0.0	27.2	35.6	0.0	0.0	0.0	0.0	37.1	0.0
Hong Kong, China	0.0	13.0	8.4	0.0	0.0	0.0	0.0	78.5	0.0
Australia	1.5	8.8	16.7	0.0	0.1	0.2	0.2	72.8	0.0
Japan	0.0	45.0	11.8	0.2	0.0	0.0	0.3	42.0	1.0
Singapore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Chinese Taipei	0.0	21.8	6.5	0.0	0.0	0.0	0.0	71.7	0.0
New Zealand	13.5	12.2	17.2	0.0	0.0	0.3	0.3	56.8	0.0
Brunei Darussalam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Korea, Rep. of	0.0	33.5	14.5	0.0	0.0	1.5	1.5	49.5	0.9
Chile	0.0	26.7	10.3	0.0	0.0	0.0	0.0	63.0	0.0
Malaysia	0.0	26.2	0.7	0.0	0.0	0.0	0.0	73.1	0.0
Russian Federation	1.5	4.1	13.3	0.0	0.0	0.1	0.1	29.4	51.6
Mexico	0.0	45.3	5.5	0.0	2.1	0.0	2.1	47.0	0.0
Thailand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
China, People's Rep. of	13.3	51.8	7.6	0.0	0.0	0.0	0.0	25.2	2.1
Peru	0.0	89.9	0.0	0.0	0.0	0.0	0.0	10.1	0.0
Philippines	0.0	44.2	0.0	0.0	0.0	0.0	0.0	55.8	0.0
Indonesia	0.0	14.5	55.3	0.0	0.0	3.5	3.5	26.8	0.0
Viet Nam	35.3	54.9	0.0	0.0	0.0	0.0	0.0	9.8	0.0
Papua New Guinea a	0.0	38.0	0.0	0.0	0.0	0.0	0.0	62.0	0.0
APEC	2.2	21.6	25.9	0.1	0.0	0.5	0.6	46.6	3.2
higher income	0.8	18.6	29.3	0.2	0.0	0.5	0.7	50.1	0.4
lower income	7.5	33.2	12.1	0.0	0.1	0.3	0.4	32.7	14.0
world	8.4	42.3	16.0	0.0	0.1	13.7	13.8	16.2	3.3

a Based on 2003 data. Includes residential, commercial and public services. **b** Includes solar, wind, tide and wave energy.
Sources: IEA (2006); EGEDA (2006).

table 14 **fuel shares in final energy consumption (TFEC), by APEC economy, 2004 – residential**

	coal	oil	gas	geo-thermal	solar/wind etc a	combustible renewables and waste	total	electricity	heat
				renewables					
	%	%	%	%	%	%	%	%	%
United States	0.0	11.6	42.9	0.2	0.5	3.0	3.6	41.9	0.0
Canada	0.1	8.5	44.4	0.0	0.0	5.9	5.9	41.2	0.0
Hong Kong, China	0.0	3.7	26.4	0.0	0.0	3.9	3.9	66.0	0.0
Australia	0.0	3.6	29.0	0.0	0.6	16.3	17.0	50.4	0.0
Japan	0.0	31.2	18.4	0.0	1.2	0.1	1.2	49.1	0.1
Singapore	0.0	0.0	7.4	0.0	0.0	0.0	0.0	92.6	0.0
Chinese Taipei	0.0	22.6	14.5	0.0	0.0	0.0	0.0	62.9	0.0
New Zealand	1.4	3.7	10.4	4.0	0.4	4.4	8.8	75.9	0.0
Brunei Darussalam	0.0	31.0	0.0	0.0	0.0	0.0	0.0	69.0	0.0
Korea, Rep. of	3.8	19.6	44.6	0.0	0.2	0.3	0.5	24.1	7.4
Chile	0.0	15.9	6.9	0.0	0.0	62.3	62.3	14.9	0.0
Malaysia	0.0	19.7	0.1	0.0	0.0	44.2	44.2	36.0	0.0
Russian Federation	3.8	3.3	31.7	0.0	0.0	1.1	1.1	9.1	51.0
Mexico	0.0	41.6	4.8	0.0	0.0	34.2	34.2	19.5	0.0
Thailand	0.0	18.4	0.0	0.0	0.0	59.8	59.8	21.9	0.0
China, People's Rep. of	14.1	5.5	2.8	0.0	0.0	68.0	68.0	6.6	3.1
Peru	0.0	19.8	0.0	0.0	1.6	58.9	60.5	19.7	0.0
Philippines	0.0	19.7	0.0	0.0	0.0	57.4	57.4	22.9	0.0
Indonesia	0.0	17.5	0.0	0.0	0.0	76.3	76.3	6.1	0.0
Viet Nam	4.3	2.0	0.0	0.0	0.0	87.7	87.7	6.0	0.0
Papua New Guinea	na	na	na	na	na	na	na	na	na
APEC	5.4	10.2	20.9	0.1	0.2	33.2	33.4	21.8	8.3
higher income	0.2	14.0	39.0	0.1	0.5	3.0	3.7	42.8	0.3
lower income	8.8	7.7	9.1	0.0	0.0	52.8	52.8	8.2	13.4
world	8.4	42.3	16.0	0.0	0.1	13.7	13.8	16.2	3.3

a Includes solar, wind, tide and wave energy. **na** Not available.
Sources: IEA (2006); EGEDA (2006).

table 15 **self sufficiency in energy and specific fuel types, by APEC economy, 2004 a**

	coal	oil	gas	nuclear	renewables	total
	%	%	%	%	%	%
United States	100.2	35.8	85.2	100.0	100.0	70.6
Canada	112.4	152.3	193.1	100.0	100.0	147.2
Hong Kong, China	0.0	0.0	0.0	–	100.0	0.3
Australia	389.4	82.7	140.7	–	100.0	226.1
Japan	0.0	0.9	3.8	100.0	100.0	18.1
Singapore	0.0	0.0	0.0	–	100.0	0.0
Chinese Taipei	0.0	0.1	7.8	100.0	100.0	12.2
New Zealand	164.4	16.4	100.0	–	100.0	73.5
Brunei Darussalam	–	1437.3	526.9	–	100.0	770.6
Korea, Rep. of	2.7	0.4	0.0	100.0	100.0	17.9
Chile	3.5	3.2	23.3	–	100.0	30.2
Malaysia	–	141.6	526.9	–	100.0	770.6
Russian Federation	124.9	350.4	146.9	100.0	100.0	180.4
Mexico	66.6	202.9	81.2	100.0	100.0	153.3
Thailand	56.1	22.7	71.9	–	100.0	51.8
China, People's Rep. of	106.1	56.6	104.3	100.0	100.0	95.5
Peru	1.7	62.4	100.0	–	100.0	71.8
Philippines	22.0	0.1	100.0	–	100.0	52.8
Indonesia	365.6	86.9	198.4	–	100.0	148.2
Viet Nam	171.1	175.6	100.0	–	100.0	130.0
Papua New Guinea **a**	na	na	na	na	na	na
APEC **b**	103.5	66.6	108.6	100.0	100.0	90.2
higher income	92.9	35.1	87.1	100.0	100.0	68.5
lower income	111.2	132.7	138.7	100.0	100.0	117.4
world	99.1	104.3	100.6	100.0	100.0	101.4

a Energy production as a percentage of total primary energy consumption (TPEC), based on IEA data. **b** APEC total excludes Papua New Guinea. **na** Not available. – Negligible/not available.
Source: Based on IEA (2006).

table 16 coal, oil and gas proved reserves, 2005

	coal		oil		gas	
	level	world share	level	world share	level	world share
	Gt	%	Gt	%	trillion m^3	%
United States	247	27.1	29	2.4	5	3.0
Canada	7	0.7	17	1.4	2	0.9
Hong Kong, China	–	–	–	–	–	–
Australia	78.5	8.6	4.0	0.3	2.52	1.4
Japan	0.4	0.04	–	–	–	–
Singapore	–	–	–	–	–	–
Chinese Taipei	–	–	–	–	–	–
New Zealand	0.6	0.1	–	–	–	–
Brunei Darussalam	–	–	1.1	0.1	2.4	1.3
Korea, Rep. of	0.1	0.01	–	–	–	–
Chile	–	–	–	–	–	–
Malaysia	–	–	–	–	2.5	1.4
Russian Federation	–	–	–	–	–	–
Mexico	1	0.1	14	1.1	0.41	0.2
Thailand	1.4	0.1	–	–	0.4	0.2
China, People's Rep. of	114.5	12.6	16.0	1.3	2.4	1.3
Peru			1	0.1	0.33	0.2
Philippines	–	–	–	–	–	–
Indonesia	5.0	0.5	4.3	0.4	2.8	1.5
Viet Nam	0.2	0.0	3.1	0.3	0.2	0.1
Papua New Guinea **a**	–	–	–	–	0.43	0.2
APEC **b**	455	50.0	89	7.4	21	11.8
higher income	333	36.6	51	4.2	12	6.6
lower income	122	13	38	3	9	5
world	909.1	100.0	1200.7	100.0	179.83	100.0

na Not available. – Negligible/not available.
Source: BP (2006).

B appendix

energy trade in the APEC region

table 17 **coal trade in the APEC region, 2005**

	to								
	Canada	**Chile**	**China People's Rep. of**	**Hong Kong (China)**	**Japan**	**Korea Rep. of**	**Malaysia**	**Mexico**	**New Zealand**
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt
from									
Australia	0	0	6	0	104	31	3	3	0.1
Canada	0	0	3	0	0	0	0	0.3	0
China, People's Rep. of	0.5	0	0	0.9	23	21	0.05	0.002	0
Indonesia	0	1	2	10	27	14	7	0	1
New Zealand	0	0	0.2	0	1	0	0	0	0
Russian Federation	0.1	0	1	0.1	10	4	0	0	0
United States	12	0	0.01	0	1	1	0	1	0
Viet Nam	0	0	10	0	2	0.4	0	0	0
imports from APEC	12	1	23	11	169	71	10	4	1
total imports	14.0	3.3	26.1	10.8	180.7	74.9	10.5	4.1	1.1
share of imports sourced from APEC economies (%)	89	34	88	100	94	95	99	98	100
APEC share in world imports	2	0.4	3	1	23	10	1	1	0.1

continued...

table 17 **coal trade in the APEC region, 2005** *continued*

	to								
	Philippines	**Chinese Taipei**	**Thailand**	**United States**	**Viet Nam**	**exports to APEC**	**total exports**	**share of exports to APEC economies**	**APEC share in world exports**
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	%	%
from									
Australia	0.1	20	0	0.2	0	166	233	71	22
Canada	0	1	0	2	0	6	28	23	1
China, People's Rep. of	2	20	0	0.02	0.1	68	72	94	9
Indonesia	4	19	6	2	0.3	95	129	74	12
New Zealand	0	0	0	0.04	0	1	1	100	0.2
Russian Federation	0	1	0	0.4	0	16	79	21	2
United States	0	0.1	0	0	0	15	45	34	2
Viet Nam	0	0.04	0	0.1	0	13	16	81	2
total imports	6.0	60	6.4	5	0.4	381	602	63	49
imports from APEC	6.1	61.4	8.5	27.6	0.4	429	773	56	56
share of imports sourced from APEC economies (%)	98	98	75	17	96	89	78	–	–
APEC share in world imports	1	8	1	4	0.1	56	78	–	–

Source: IEA (2006a, b).

table 18 **crude oil trade in the APEC region, 2005**

	to					
	Australiasia	**Canada**	**People's Republic of China**	**Japan**	**Mexico**	**United states**
	Mt	Mt	Mt	Mt	Mt	Mt
from						
Australasia	0	0	1	3	0	1
China, People's Rep. of	0.4	0.1	0	2	0	2
Canada	0	0	0	0.3	0.1	107
Japan	0.4	0	3	0	0	0
Mexico	0	2	0	0	0	82
United States	0	7	0.4	4	10	0
Other Asia Pacific	27	0.2	30	25	0.1	8
imports from APEC	28	9	35	35	10	200
total imports	36	60	167	258	16	667
share of imports sourced from APEC economies (%)	78	16	21	13	66	30

	to				
	other Asia Pacific	**exports to APEC**	**total exports**	**share of exports to APEC economies**	**APEC share in world**
	Mt	Mt	Mt	%	%
from					
Australasia	6	11	11	100	0.4
China, People's Rep. of	14	18	21	89	1
Canada	0	108	109	99	4
Japan	1	5	5	92	0.2
Mexico	2	85	103	83	3
United States	4	25	54	47	1
Other Asia Pacific	15	105	113	93	4
imports from APEC	41	357	415	86	15
total imports	469	1 672	2 462	68	68
share of imports sourced from APEC economies (%)	9	21	17	–	–

Source: BP (2006).

table 19 **natural gas trade in the APEC region, 2005**

from	to: Canada billion m³	Japan billion m³	Republic of Korea billion m³	Mexico billion m³	Chinese Taipei billion m³	Singapore billion m³
Australia	0	13	1	0	0.4	0
Brunei Darussalam	0	8	1	0	0	0
Canada	0	0	0	0	0	0
Indonesia	0	19	8	0	5	5
Malaysia	0	18	6	0	4	2
Mexico	0	0	0	0	0	0
Russian Federation	0	0	0	0	0	0
United States	10	2	0	10	0	0
imports from APEC	10	60	16	10	9	7
total imports	10	76	30	10	10	7
share of imports sourced from APEC economies (%)	100	78	52	100	98	100

from	to: Thailand billion m³	United States billion m³	exports to APEC billion m³	total exports billion m³	share of exports to APEC economies %	APEC share in world exports %
Australia	0	0	15	15	98	2
Brunei Darussalam	0	0	9	9	100	1
Canada	0	104	104	104	100	14
Indonesia	0	0	36	36	100	5
Malaysia	0	0.3	30	30	99	4
Mexico	0	0.03	0	0.03	100	0
Russian Federation	0	0	0	151	0	0
United States	0	0	22	22	100	3
imports from APEC	0	104	217	368	59	30
total imports	9	122	274	721	38	38
share of imports sourced from APEC economies (%)	0	86	79	51	–	–

Source: BP (2006).

C appendix

APEC energy policy setting for the electricity sector, by geographic region

This appendix provides an outline of the energy policy setting for the electricity sector in several subregions of the APEC area, with an emphasis on electricity generation. Subregions include north America, Australia and New Zealand, south east Asia, south America, north east Asia, China and the Russian Federation.

north America

The United States took a key energy policy initiative in 2005 with its release of the *Energy Policy Act of 2005*. This act opens the way for new sources of investment for infrastructure investment, including power lines, pipelines and underground bundled cables, all of which are required to meet the United States' future energy needs (IEA 2006a).

In Canada, power sector reform is aimed at moving away from coal toward greater use of nuclear and renewable energy sources, in particular hydroelectricity. For example, Ontario has put in place plans that double the electricity drawn from renewable sources by 2025. Canada also provides tax concessions for expenditure on technologies for energy conservation and renewable energy production to meet local demand.

Power sector reform is high on the agenda of policy makers in Mexico. The sector suffers in general from pricing issues, with some of the highest energy prices in the APEC region. In addition there is a high incidence of nondistribution losses.

A major focus in Mexico's energy policy framework is rural electrification. For communities without access to the grid the government, in partnership with the private sector, has implemented various electrification programs based on photovoltaic systems. In addition to receiving funding, communities are informed of the mechanics of the solar systems and trained to operate and maintain the infrastructure. This is believed to be a key factor for the success of the program as it has promoted the uptake of photovoltaic as well as hybrid wind/photovoltaic systems across rural Mexico (WEC 1999).

Australia and New Zealand

Energy policy in Australia and New Zealand is reliant on market mechanisms that allows industries to operate in a regime that holds specific energy sector legislation to a minimum. Competitive markets for energy are at advanced stages of development in these countries, with a high level of private sector participation. For example, in Australian jurisdictions, retail contestability in the national electricity market has been established, except for Queensland and Tasmania that entered the so-called 'national electricity market' only in 2005.

Both Australia and New Zealand face a challenge in marshalling future investment requirements in the power sector. For example, in Australia, the recently formed Australian Energy Regulator is seeking $23 billion over the next fifteen years in infrastructure investments. This task is made difficult in Australia because of recent lack of interest in the power sector by foreign investors, some of which are seeking to exit the sector. The Australian Energy Regulator is in the process of absorbing the function of thirteen government bodies by the end of 2007, in a bid to attract further foreign investment into the power sector.

Energy policy in these countries reflects their respective resource availability. For example, while much of the power sector in Australia is based on coal fired power, New Zealand is predominantly dependent on hydroelectricity, contributing around 65 per cent of electricity generation in 2004.

south east Asia

Prior to the Asian financial downturn in 1997-98, many south east Asian economies had active programs to introduce private sector competition in the power sector through the establishment of 'independent power producers' (IPPs). The downturn led to a substantial decline in energy demand across the region, and financial strains in state run utilities, making it difficult for them to pay for all the power that was contracted for under power purchase agreements. Although the program has been slowed by the downturn, the IPP program is still being actively pursued in many south east Asian countries.

Many economies in the region face severe electricity problems owing to a lack of investment in the sector in recent years. Much of the region is focusing investment into lower cost coal and gas fired facilities and, where resources exist, into hydroelectricity.

South east Asian economies are at different stages of moving toward competitive markets in the power sector. For example, in February 2005, the Indonesian Government introduced legislation that clears the way for full private ownership of electricity generation assets. Despite this, foreign investors have largely avoided investment in the sector's IPP program because of the poor financial performance of the state electricity utility and an uncertain legal climate. Malaysia opened up the electricity market to IPP participation in 1994, with fifteen IPPs licensed. Likewise, the Philippines has substantially deregulated its energy sector in recent years and has offered new incentives for foreign investment.

Reflecting significant natural gas resources in the region, many south east Asian economies have actively promoted natural gas in the generation mix, including the Philippines. While a significant proportion of Malaysia's electricity is gas fired, the government has adopted a policy of attempting to reduce the country's reliance on natural gas for electric power generation in favour of coal fired generation. The Malaysian government is also pursuing an incremental increase in hydroelectric capacity through the staged completion of the 2400 megawatt Bakun Dam project.

Geothermal power is also significant in the region. For example, the Philippines Government has set a goal of increasing geothermal power capacity to 3100 megawatts in a decade, up from 1900 megawatts in 2006.

south America

Energy markets in Peru and Chile are partially privatised, with the level of private ownership being high. Both Chile and Peru are relatively well endowed with hydro resources, with hydroelectricity contributing 45 per cent and 72 per cent of electricity generation respectively in 2004. However, drought periodically causes shortfalls. To cover electricity demand in dry years, governments in these economies have targeted natural gas as a means of diversifying the electricity generation mix.

Interconnection of regional electricity networks is also being actively pursued by both Chile and Peru. Peru seeks to export electricity to adjoining countries, including Ecuador, Chile and Bolivia, as part of a larger movement by the Andean community to create a common electricity market. The Peruvian and Chilean Governments have also begun negotiations for an interconnection.

north east Asia

Japan began the process of liberalising its electricity market in the early 1990s, with competition introduced into the generation sector by 1995 through the passing of the Electricity Utilities Industry Law. From 1996, nonelectric power companies are able to sell electricity to utilities, explaining in part the rise of cogeneration technologies in Japan. Retail contestability was introduced for large power end users in 2000, with this regime being extended to smaller energy users in 2005.

The Republic of Korea unbundled assets held in the state owned Korean Electric Power Corporation (KEPCO) in 2001 into separate entities that focus on generation, transmission and distribution units and has allowed some independent power producers into the electricity market. However, while plans exist to privatise KEPCO, the Korean Government decided in June 2004 to limit the privatisation of the electric power sector to generation facilities, retaining ownership over the transmission and distribution assets of KEPCO.

China

In recent years, energy has become a focus area for Chinese policy makers. Spurred on by electricity shortages from early 2003, and coal sector imbalances, work on a comprehensive energy law was initiated, as were efforts to adjust laws on oil, natural gas and coal, and new and renewable energy. For example, the 11th Five Year Plan announced in March 2006 outlines an ambitious goal of reducing the economy's energy intensity by 20 per cent in 2010 compared with 2005. Policies outlined in the plan have the objectives of improving the way in which coal is used; diversification of energy sources by increasing the use of renewable energy, natural gas, nuclear and coal bed methane; optimising energy supply through promoting improved extraction and generation technologies; limiting the adverse impacts of hydroelectric projects, and closing small and/or dangerous coal mines and inefficient power plants.

Drafting of legislation and specifications to achieve targets set in the five year plan are proceeding (IEA 2006a). The main supply side initiatives incorporated into the plan are:

- upgrading coal burning industrial boilers and kilns
- promoting cogeneration for district heating and
- utilising waste heat and pressure.

China is taking gradual steps toward liberalising energy markets. To date, only coal prices have been substantially deregulated, with prices of other energy sources, including oil products and electricity being tightly controlled. The lack of control on coal prices, while electricity prices remain controlled, has required the central government to adjust upwards the electricity tariff paid by consumers in May 2005 and June 2006, in order to allow generators to pass on recent price rises to consumers. In addition, in June 2006, surcharges to feed-in tariffs were included for various types of generators, in particular to provide incentives for hydro power, and other renewable energy projects, as well as desulfurisation equipment, sending a signal to energy supply infrastructure investors to finance cleaner power plants.

In the area of energy sector R&D, the Interim Regulation and the Guiding Catalogue for Adjustment of Industrial Structure, released in December 2005, encouraged exploration and development of natural gas hydrates, and construction of supercritical and ultra supercritical power plants with a size of at least 600 megawatts. Restricted activities under this regulation include small scale coal mining activities, and small scale ordinary coal fired generation with a generation capacity of 300 megawatts or less (IEA 2006a).

Russian Federation

The Russian Government maintains a tight hold on the economy's oil and gas sector. Aging infrastructure and inefficiencies in the gas sector have led the government to allow some foreign ownership of Gazprom, the state owned gas supply and distribution company. In contrast, Russia's coal industry has been substantially deregulated — with World Bank assistance — with about 77 per cent of production coming from independent producers.

Russia's electricity sector requires substantial investment to lift performance, and major reforms are envisaged by the end of the decade. The Russian Federation has made nuclear and hydroelectricity generation, particularly in the economy's far east, priorities in boosting electricity generation. In addition, the government is promoting advanced coal fired capacity in the coal rich Siberian region and efficient natural gas fired capacity for the western and far eastern areas of the country.

While wholesale competition and choice of electricity supplier are nonexistent for consumers in the Russian Federation it is envisaged that implementation of these market structures will begin in 2007, after assets of the monopoly supplier are partially privatised. In line with other privatisation models followed in recent years in the APEC region, the monopoly supplier, UES, will privatise its generation and distribution assets, but the state will retain control of grid. Differential electricity tariffs between regions are also planned to be removed.

technological development for electricity generation

fossil fuel based electricity generation technologies

There are two principal types of fossil fuel power generation: steam turbines and gas turbines. In a steam turbine coal, oil or natural gas are burned to heat water to produce superheated steam that is used to drive a turbine. The efficiency by which the generation unit converts energy stored in the input fuels to electricity is largely a positive function of the pressure and temperature levels reached in the conversion process. Steam turbines can be subcritical (up to 540 degrees), super-critical (540 degrees and above) or ultra supercritical (580 degrees and above) depending on the temperature and pressure of the steam. The process is similar when gas turbines are used except, in a simple cycle configuration, fuels are burned to create hot gases to drive the turbine. Gas and steam turbines can be configured consecutively ('combined cycle') where waste heat from a gas turbine is used to produce steam to generate additional electricity.

Advanced energy technologies for fossil fuel fired power generation generally fall into two categories: combustion process improvement and emission control. Technologies designed to enhance the combustion process (which not only improves thermal efficiency but also reduces greenhouse gas emissions) include pressurised fluidised bed and integrated gasification technologies. Emission control technologies include flue gas desulfurisation and selective catalytic reduction and carbon capture and storage technologies.

coal fired technologies

stokers and stoker cyclone

These technologies combust coarse or crushed coal to drive conventional steam turbines. They can fire coals that are not suited to pulverisation and are employed in some applications to save capital and operating costs at the expense of thermal efficiency.

pulverised coal (PC)

In this system, coal is pulverised and fed into burners where it is combusted at high temperature. This process raises high pressure steam that is used to drive a steam turbine and generate electricity.

Three systems are considered, subcritical, supercritical and ultra supercritical. Supercritical and ultra supercritical power plants require higher quality construction materials to cope with more extreme conditions, and cost more than subcritical generation units. This increased cost is balanced against a higher thermal efficiency. Because of the high temperatures and pressures reached in ultra supercritical plants, the boiler and steam turbine cost can be as much as 50 per cent higher for an ultra supercritical plant than a supercritical plant.

fluidised bed combustion (FBC)

In an FBC plant, crushed coal mixed with limestone is combusted in a suspended bed. The turbulent state of the gas improves combustion, heat transfer and recovery of waste products. Fluidised beds generally have higher capital costs than conventional pulverised coal systems but produce less nitrogen and sulfur oxides, although particulate removal and emission control systems can be added depending on emission standards. FBC power generation plants are particularly suited to clean burning of low grade coals and can also be fuelled with waste products, such as municipal waste and tyres. Thermal efficiency of these power generation plants is around 30–35 per cent.

pressurised fluidised bed combustion (PFBC)

Pressurised fluidised bed combustion is an advanced bed technology that combusts coal at 10–20 times atmospheric pressure, with the unique advantage of enabling the use of gas turbines for higher cycle efficiency. Exhaust gas from the bed is cleaned to reduce its concentration of particulates prior to expansion through the gas turbine. The steam turbine produces 80–90 per cent of the generated power, and the gas turbine 10–20 per cent. An electrostatic precipitator or baghouse filter may be located upstream of the stack in order to ensure that the particulate concentration of the gas meets local, or national emissions requirements. There are several commercial scale PFBC power generation plants in operation worldwide.

PFBC power generation plants have several advantages over other coal technologies including the flexibility to operate successfully with high ash or high moisture coals. They also have low sulfur dioxide and nitrous oxide emissions, are compact and can be sited within the boundaries of existing power generation plants. The thermal efficiency of PFBC is around 40 per cent and is expected to improve to closer to 45 per cent in the coming decade (Nautilus Institute 1999).

integrated gasification combined cycle (IGCC)

In the IGCC process, coal is not combusted but reacted with oxygen and steam to produce a syngas consisting predominantly of carbon monoxide and hydrogen. The syngas is cleaned of impurities and burned in a gas turbine, driving a steam cycle that generates electricity. The exhaust heat is also used to drive a steam cycle, producing additional electricity. Around 60–70 per cent of the power comes from the gas turbine and 30–40 per cent from the steam cycle.

IGCC power generation plants allow electricity to be generated at high levels of efficiency with the combined power generation process boosting thermal efficiency by as much as 25 per cent above conventional coal fired power generation plants (APEC 2001). The thermal efficiency of IGCC power generation plant is around 45 per cent but improvements of up to 5 percentage points are expected to be achieved by 2020 (IEA 2006c). Further, carbon dioxide can be captured at a lower cost from the high pressure and concentrated syngas from an IGCC power generation plants than from the flue gas of conventional pulverised coal fired power stations. IGCC systems also produce less solid waste and lower emissions of sulfur dioxide, and nitrous oxides than conventional PC power generation plants. IGCC systems also use relatively small volumes of cooling water and so can be an attractive option for areas lacking adequate water. IGCC power generation plants can also be used for the coproduction of hydrogen for use in commercial purposes, such as in the manufacture of chemicals and liquid fuels. The sale of hydrogen or syngas to produce these products has the potential to offset some of the cost of electricity generation using IGCC power generation plants (Coal21 2004).

lignite drying

Lignite drying allows brown coal to be used in IGCC power generation plants, where an integrated drying process is not already employed, by reducing the water content of brown coal. A number of different technologies are being tested, including integrated drying gasification combined cycle (IDGCC) power generation plants. These power generation plants may be able to operate at efficiencies of up to 60 per cent but demonstration is required to further reduce costs and improve reliability to a commercial level (AGO 2000; Coal21 2004).

ultra clean coal (UCC)

Ultra clean coal is a chemically pulverised coal product that is sufficiently pure to be used as a replacement for natural gas in high efficiency gas turbine generators. Ultra clean coals are not considered substitutes for conventional coal in traditional power generating systems and are instead used as alternatives in heavy fuel oil and gas turbines. Ultra clean coals are cost competitive with these fuels on an energy equivalent basis (Coal21 2004). The high efficiency rate compared with conventional coal power generation plants represents a potential reduction in greenhouse gas emissions.

gas and oil fired technologies

internal combustion engines

Internal combustion engines are well proven, reliable equipment that are commonly used in remote locations such as islands and rural areas, or even for peaking power applications.

subcritical and supercritical steam

Conventional subcritical and supercritical steam boilers with steam turbines is the most common existing technology for large scale gas and oil fired power generation plants in developed APEC economies.

simple cycle

Simple (or open) cycle combustion turbine power generation plants use a compressor to compress the inlet air upstream of a combustion chamber. The fuel is ignited to produce a high temperature, high pressure gas that enters and expands through the turbine section. The combustion gases in a gas turbine power the turbine directly, rather than requiring heat transfer to a water/steam cycle to power a steam turbine. The turbine section powers both the generator and compressor. The combustion turbine's energy conversion typically ranges between 30 and 35 per cent efficiency as a simple cycle (LHV).

The low capital cost of installing these types of turbines makes them especially suited for peak load operation, since their lower efficiency is less important when their annual load factor is low.

natural gas combined cycle (NGCC)

In an NGCC power generation plant, natural gas is combusted in a gas turbine and the waste gases in the turbine are recovered and used to raise steam, which drives a steam turbine generating additional electricity. Thus electricity is produced both from the gas turbine shaft and the steam turbine, improving the overall efficiency of the power generation plant.

combined heat and power (CHP)

CHP (or cogeneration) plants use heat for electricity generation and for another form of useful thermal energy (steam or hot water) for manufacturing processes or central heating. CHP cogeneration plant is more commonly associated with gas and oil combustion technologies than with coal. Internal combustion engines, steam boilers and gas turbines are all applicable to cogeneration of electricity and steam, although fuel cells and microturbines are driving the further development and adoption of CHP systems. There are two types of CHP systems. The first is where a manufacturing process uses high temperature steam first and a waste heat recovery process recaptures the unused energy and uses it to drive a steam turbine to generate electricity. Common sources of waste heat include district heating/cooling and industrial processes. The second is where waste heat from electricity generation is used for another purpose such as space heating.

traditional renewable energy technologies

combustible renewables and waste

Combusting biomass for electricity and heat applications, both as stand alone systems for use in other agricultural processes and for grid augmentation, is becoming more prevalent in developing countries in the APEC region, particularly in regions generating significant quantities of agricultural residues. For example, many 'clean development mechanism' projects in developing APEC economies focus on using agricultural residues such as rice husks, bagasse and palm oil residues for electricity generation. The wide availability of these agricultural residues in the APEC region, a low cost labour pool, and the lower startup investment required relative to more expensive options of new renewable energy technologies, including wind and solar photovoltaic power, help make these types of renewable energy technologies viable options for electricity generation. This is especially the case if projects are cofinanced through access to multilateral aid or CDM credits.

Combusting municipal waste for electricity generation makes a greater contribution to the renewable energy mix in high income rather than low income countries. The main reason for this is that the urban waste stream is more concentrated in high income countries. For example, in Indonesia, Malaysia and the Philippines, only 10–30 per cent of municipal waste is collected and disposed of at land fill sites, with most waste being either composted or dumped openly (UNEP 2006). In addition, suitable landfill sites are becoming less available in high income countries, and combusting municipal waste allows these countries to avoid creating new land fill sites.

hydro power

Large scale hydro power is a significant source of renewable energy in the APEC region. While there are significant untapped hydro resources in the APEC region, particularly in China and the south east Asian region, further development of large scale hydro power imposes significant environmental costs in both the area where dams are established, through flooding, and downstream, through reduced water flows. Also, many economies in the APEC region, while having significant hydro resource potential are not large enough energy consumers to justify the creation of large scale hydro plants.

geothermal energy

There is substantial geothermal energy potential locked below the earth's crust, much of which cannot be economically exploited with existing technology. Of the four main types of geothermal energy — hydrothermal, geopressured, hot dry rock and magma — only hydrothermal has been developed on a commercial scale, mainly because the resource can be harvested at a relatively shallow depth (100–4500 metres), and is a cost competitive source of energy when compared with fossil fuel, nuclear or hydroelectricity. This form of geothermal energy potential only exists in limited geographic areas, and is concentrated in areas undergoing earthquake and volcanic activity, usually at the junctions of tectonic plates that make up the earth's crust.

The main economies of the APEC region where these geothermal resources have been successfully tapped include the Philippines, New Zealand and Indonesia. While there is further potential for the development of this resource in the APEC region, in many cases the resources are too far from existing electricity grids to make their development economic. For example, while Indonesia has a substantial resource potential in hydrothermal geothermal energy (around 20000 megawatts), only around 4 per cent of this resource is currently used, as the resources are in very remote areas of the island archipelago nation, far from existing grids (NEDO 2006).

new renewable energy technologies

wind power

Wind power is again location specific and usually requires siting in elevated or open positions to be efficient in power generation. Offshore locations are usually preferred for siting of wind farms, although efficiency gains need to be balanced against the higher cost of construction. For example, offshore siting is used extensively in northern Europe for the establishment of wind farms.

Even at the ideal location, wind power is only able to achieve a relatively low load factor when compared with fossil fuel and nuclear based generating plants. The intermittent nature of this generation technology can be overcome to a degree by dispersing wind turbines across a wide area, so that at least some turbines are likely to be generating at all times of the day.

In addition suitable wind farm areas may not coincide with the location of the electricity grid, making the integration of the electricity supply from these farms into the national electricity market costly. A further issue is that wind farms are sometimes rejected by the communities near to where they are to be located because of poor aesthetics, excessive noise or the hazard they represent to birds.

solar power

Solar energy is the most abundant energy source available to satisfy global energy demand. The problem is that it is dispersed over a wide area and costly to convert into useful electricity. The two main types of solar technologies used for electricity generation are concentrating solar power, and photovoltaic.

Concentrating solar power technologies use mirrors – typically in a trough or parabolic configuration – to concentrate solar energy to heat a working fluid that enables steam to be raised that in turn is used to turn a turbine to produce electricity. This technology is the most widely used solar technology. These systems can be sized for village power (up to 10 kilowatts) or grid connected applications (up to 100 megawatts). Trough configurations are most suited to large central power generation, and have the advantage of being able to be sited with conventional small fossil fuel fired generators – typically simple cycle gas fired turbines, but can also be integrated with existing coal fired generators. Using this hybrid approach, concentrating solar power technologies are able to offset solar power intermittency — as solar systems are unable to produce power after sunset — and provide a more reliable flow of electricity supply to grids. Some storage potential is also inherent in the system as latent heat in the working fluid can continue to produce electricity for some hours into the evening. Alternatively, for large central power generation (50–200 megawatts) mirrors can be placed around a tower concentrating solar rays onto a receiver at the top of the tower containing the working fluid. Parabolic configurations are more suited to small scale generators, and range up to 5 megawatts, especially in areas where access to grid supplied electricity is not available.

The cost of concentrating solar power technologies for electricity generation is relatively high compared with other renewable energy technologies, and is strongly dependent on the siting of these plants, with arid and semi arid areas receiving abundant sunlight usually being the preferred site. These sites may not correspond to population areas, making transmission of power generated prohibitive but making them highly suited to providing distributed electricity generation. The technology also relies on small scale fossil fuel based generation, usually simple cycle gas fired turbines with low efficiency (40–45 per cent), compared with larger combined cycle gas fired turbines that have efficiencies reaching 60 per cent.

The cost of this technology is expected to decline over time through research and development in solar concentrator performance and improvement in the performance of system components. Such improvements will allow the construction of larger plants where economies of scale can be reaped. For example, in the United States, two large solar plants are to be constructed in southern California under the state's Renewable Portfolio Standard, with the first plant (500 megawatts) due for completion in 2012 (IEA 2006c). Future cost reductions will also be driven through the increasing trend to combine this technology with a more efficient backup power generator such as the combined cycle gas fired technology.

The solar photovoltaic route to electricity generation involves the use of semiconductors — encapsulated into modules with up to several hundred watts capacity — to convert light directly into electricity. These modules are combined into larger power arrays as required and can be connected directly to either consumers or the grid. They typically work in conjunction with battery storage, that releases electricity as required, and in conjunction with backup electricity from the grid as required.

The cost of photovoltaic electricity is substantially higher than concentrating solar power technologies. The technology is currently only economic in remote area applications, where grid power is not available, or for providing power in niche applications, such as traffic signalling devices and weather stations and running small scale equipment.

The main cost in the system is in the manufacture of cells. Given the low efficiency of cells in converting sunlight to electricity (6–15 per cent), improvement in efficiency will bring down system costs significantly. Also low efficiency causes high balance of system costs in grid connected generators. Cost reductions are possible in future through further research and development into thin film technologies, and through hybrid systems that combine solar concentrators with photovoltaic receivers to produce electricity, and hot water.

While solar power is not as location specific as geothermal or wind power, it is a more costly technology to adopt than alternative renewable energy technologies. Also, land requirements for solar panels are large relative to the power generated from them.

hot rock geothermal energy

A new renewable energy source that is being increasingly investigated is electricity production from the heat energy in hot dry rocks deep below the earth's surface. This form of geothermal energy is more widely distributed than hydrothermal geothermal energy. But the extraction task is more costly as the resource needs to be tapped at much greater depths (3–5 kilometres).

Hot rock geothermal energy requires specific geological structures, in particular the existence of high heat generating granites, that are close enough to an existing electricity grid to allow a cost effective interconnection of electricity produced from these sources. This technology is yet to be demonstrated, and research is continuing to explore the merits of this technology further.

tidal power

Technologies that use water currents to generate electricity are still at a relatively early stage of development. Apart from several demonstration projects, there are few commercial electricity generators using tidal energy as the feedstock. Exceptions in the APEC region are a 20 megawatt unit at Annapolis Royal in Canada (built in the 1980s) and a unit in the Russian Federation (IEA 2006c).

Tidal power is very site specific, with only around twenty suitable sites identified worldwide (Energy Resources 2006). The main advantage is that the power from tidal power is reliable. The main disadvantages are that building the barrages that tidal power require across estuaries is very expensive and imposes significant environmental costs in the areas where they are built.

Tidal power can also be harvested using offshore turbines. This research area is relatively new and demonstration projects are yet to be established. It is envisaged that the cost of this form of tidal power will be lower than current tidal power technologies, and be able to be applied in a wider area, while leaving a lesser environmental footprint (Energy Resources 2006). However, because turbines need to be installed deep below the ocean surface, significant barriers to development exist in terms of construction and decommissioning of plants, and potential impacts on marine life and interference with shipping routes.

emission control in the electricity sector

electrostatic precipitators (ESP) and fabric filters (or baghouses)

ESPs and fabric filters are the most widely used particulate emissions control technologies used on coal fired power generation plants. The choice between ESP and fabric filtration generally depends on coal type, power generation plant size and boiler type and configuration. Both technologies are highly efficient particulate removal devices, with design efficiencies in excess of 99.5 per cent.

flue gas desulfurisation (FGD)

FGD is common worldwide and has been used to suppress sulfur dioxide emissions for around thirty years. FGD can be retrofitted or incorporated into new plant. The most common method is based on flue gas scrubbing using a limewater slurry (wet scrubbers) that can capture 95 per cent or more of sulfur dioxide in the flue gas before it exits the stack. FGD technologies are continually advancing. Recent developments include the double contact flow scrubber (DCFS) where the limestone slurry contacts with the flue gas twice, ensuring higher desulfurisation efficiency and easier access for maintenance than conventional FGD systems (Japan Corporate News 2004).

selective catalytic reduction (SCR)

SCR is designed to reduce nitrous oxide emissions. In the SCR process, ammonia is injected into the flue gas and is passed through a catalytic reactor where the ammonia reacts with nitrous oxides to produce nitrogen and water. The SCR process is suitable for power generation plants that use low sulfur coal and can achieve a reduction in nitrous oxide emissions of 80–90 per cent. Combined sulfur dioxide / nitrous oxide removal processes are considered fairly complex and costly. However, emerging technologies have the potential to reduce sulfur dioxide and nitrous oxide emissions for less than the combined cost of conventional FGD for sulfur dioxide control and SCR for nitrous oxide control. Most processes are in the development stage, although some processes are commercially used on low to medium sulfur, coal fired power generation plants.

carbon capture and storage (CCS)

Carbon capture and storage is an advanced technology for reducing carbon dioxide emissions from fossil fuel fired power generation plants beyond that attainable through increases in thermal efficiency. Carbon may be captured from the electricity generation process in a number of ways and the carbon placed in a long term storage facility such as an underground aquifer. There are three generic approaches to capturing carbon dioxide from a power generation plant:

- post combustion capture – where carbon dioxide is captured from combusted products in the power generation plant flue gas. Current post combustion technologies involve chemical or physical solvent scrubbing systems. Carbon dioxide may also be captured using cooling and condensation (cryogenics), membranes or adsorption techniques;
- precombustion capture – where the carbon content of fossil fuels is reduced and a carbon dioxide rich byproduct is produced. The carbon dioxide is separated using adsorption or absorption methods and can be used, along with the remaining hydrogen, in other industrial processes.
- oxyfuel combustion – where fuel is burnt in oxygen with recycled carbon dioxide rich flue gas to increase the carbon dioxide concentration prior to capture.

Capture and compression technologies are energy intensive and result in more fuel being used per unit of output. Consequently, reductions in thermal efficiencies of up to 10 percentage points are possible. Increased costs arise through reduced overall power generation plant efficiency combined with increased capital and operating costs. These technologies are still in the early stages of development and there is significant uncertainty surrounding investment costs for commercial scale projects (DTI 2004).

advanced power generation systems

Oxyfuel combustion is a near zero emission technology that can be used with conventional supercritical and ultra supercritical pulverised coal fired power generation plants. Coal is burnt in a mixture of oxygen, rather than air, and recycled flue gas in order to increase the concentration of carbon dioxide in the flue gas to facilitate capture. While this technology has not been demonstrated, it has the potential to make carbon dioxide less costly to capture from conventional pulverised coal fired power generation plants and could provide a viable retrofit option for existing capacity, or a 'carbon capture ready' option for new pulverised coal fired power generation plants. The technology is currently very expensive both in terms of capital cost and energy consumption. It may, however, become viable at a commercial scale within the next ten to twelve years (Coal21 2004).

Advanced power generation systems of the future could also include fuel cells and magnetohydrodynamics (MHD), two technologies still in the early development stage. Fuel cells allow hydrogen from natural gas, methanol or coal gas to react electrochemically with oxygen from the air to generate electricity. The theoretical efficiency of this technology is 60 per cent and the system can achieve near zero emissions with carbon dioxide capture and storage, although the capture process will reduce efficiency. The use of fuel cells has been demonstrated at the 2 megawatt size and plans are under way to use hydrogen from coal gasification in this and other technologies.

In a coal fired magnetohydrodynamics system, coal is burned to form an extremely hot gas or plasma. This is given an electric charge by adding a seed compound such as potassium salt. When the charged gas is passed through a strong magnetic field, electricity is produced. Heat from the combustion gases is also used to produce electricity using a conventional steam turbine (Coal21 2004).

E appendix

technological development in stationary energy end use applications

This appendix provides detailed descriptions of technologies and process improvements that can provide significant energy savings to industry and households. Energy efficiency analysis can be applied at different points in the energy system, including energy using equipment, major industrial processes, supply technologies, delivery networks, and even urban form and infrastructure. Considering elements of the system together or separately will provide a different picture of energy efficiency. Decisions taken about industrial siting, energy supply, infrastructure and major industrial processes will have long lasting implications on the energy efficiency of the system, shaping decisions that take place more frequently on individual equipment (motors, air displacement systems, lighting etc).

iron and steel

Pulverised coal injection is already a widely applied technology. It is financially attractive and has resulted in substantial energy savings in recent years. Plastic waste can also be injected into blast furnaces as a substitute for coke and coal. The technology has been developed and applied in Germany and Japan. Plastic waste can also be added to the coking oven. This technology is applied commercially in Japan. In total 0.4 million tonnes of plastic waste is used a year by the Japanese iron and steel industry, equivalent to about 20 petajoules of energy a year.

The emergence of the direct reduced iron–electric arc furnace steel production route as an alternative to minimills seeking to produce higher quality steel products has led to significant developments in direct reduction technologies. Energy consumption in electric arc furnace based minimills is affected by a number of factors, including the type of electric arc furnace used, the percentage of direct reduced iron or hot metal in the charge, the technology used to produce the direct reduced iron and the heat of the charged materials.

For example, a modern electric arc furnace with scrap preheating can convert a charge of 100 per cent steel scrap to bars or flat products for around 5 gigajoules a tonne of crude steel (de Beer et al. 1998). It is estimated that this scrap preheating reduces electricity consumption by around 80 kWh a tonne of liquid steel (or around 0.7 gigajoules of energy for each tonne of crude steel produced) (IISI 1998). In general, electricity consumption in the electric arc furnace falls by around 20 kWh for each 100 degrees C increase in the charge temperature (Midrex 1999). However, if a charge of 100 per cent direct reduced iron is used in the same furnace, the total amount of energy consumed in the process would increase to around 18.5 gigajoules a tonne of crude steel, which is similar to the energy consumed by an integrated steel mill operating at best practices (de Beer et al. 1998).

additional emission reduction technologies

There are processes that steel mills can adopt to improve environmental performance. The most significant of these are coke dry quenching and flue gas desulfurisation.

Coke dry quenching involves using an inert gas (usually nitrogen) to cool the hot coke produced in coke ovens to prevent the coke from oxidising. These hot inert gases are then transferred to a steam boiler, where they can be used to generate steam or electricity for use elsewhere in the steel making process. This process is estimated to result in energy savings of up 1700 megajoules for each tonne of dry coke quenched relative to the water quenching process generally used to cool coke in the coke oven (IISI 1998). The water quenching process involves using water to cool the coke, which produces steam that is generally lost to the atmosphere. Flue gas desulfurisation systems are based around the concept of passing waste gases from fossil fuel combustion through an absorption tower containing an absorptive material, typically lime.

As the waste gases pass through the lime, dusts containing sulfur particles and other wastes are absorbed by the lime, which in some cases can be reused as gypsum. Flue gas desulfurisation systems can be used to clean the flue gases released at any stage of the steel production process, from coke and sinter production to iron making. These systems typically add both energy and other costs to steel production and are generally used in economies where environmental laws limiting sulfur dioxide emissions are in place.

aluminium

Over the longer term, the deployment of inert anodes in the aluminium industry can eliminate carbon dioxide emissions associated with the use of carbon anodes. It can also eliminate emissions of perflourocarbons (a greenhouse gas with significant global warming potential) that occur in the electrolysis process. However, this technology still requires substantial research and development to reduce wear rates of anodes to below 5 millimetres a year (IEA 2006c). The technology is expected to become commercially available only after 2030. Also, the use of this technology is only applicable to new smelters, as retrofitting old smelters would require a complete redesign of the plant. Compared with advanced Hall-Heroult smelters, the use of inert anodes could reduce electricity consumption by 10–20 per cent, in addition to the savings in terms of not using fossil fuel based anodes.

In the shorter term, future improvement in the production processes of aluminium with respect to PFCs can be driven by benchmarking data and a focus on the worst performing plants across all primary aluminium production facilities. The project will enable emission measurements to be undertaken specific to the aluminium smelter technology at each smelter, compared with an agreed and recognised standard This will provide a tool to improve aluminium production efficiency and minimise emissions.

petroleum refining and chemicals industry

Energy efficiency measures in the petroleum refining and chemicals industry are aimed at process improvements often focusing on the recycling of waste gases and heat in cracking and distillation of petrochemicals and providing additional heat in the production of chemicals. Vapour recompression in the petrochemical industry compresses the overhead vapours from distillation towers, which are then condensed in a reboiler and returned to the tower. This is a heat pump process that can significantly reduce energy consumption but with a significant capital cost. Pinch technology involves analysing all of the heating and cooling requirements in an industrial process in order to optimise heat recovery and waste heat utilisation (MK Jaccard & Associates 2004).

The ALCET process is used in the production of ethylene. Naptha, commonly used as feedstock, is initially cracked at 1590 degrees and 200 kPa and ethylene is recovered at low temperature (29.4 degrees) and 3792 kPa. The ALCET process eliminates the ethylene and methane refrigeration system and replaces it with a less expensive solvent absorption system. ALCET reduces capital cost by 25 per cent and energy requirements by 10 per cent.

About 13.3 exajoules of feedstock is used for steam cracking worldwide. This represents almost 44 per cent of the chemical and petrochemical industry's final energy use. Out of this total, only 2.1 exajoules is used for energy purposes.

Steam cracking products contain about 11.2 exajoules, of which about 1.5 exajoules is recycled to the refining industry in the form of byproducts for further processing into gasoline and other products.

membranes

Many membrane technologies that are currently in the research and development phase are being developed to replace more energy intensive traditional chemical separation processes. For example, liquid and gas membranes are an alternative to liquid–liquid extraction and cryogenic air separation (IEA 2006c).

chlorine and sodium hydroxide

Chlorine and sodium hydroxide are obtained through the electrochemical decomposition of salt, with hydrogen being produced as a byproduct. Electricity for the electrochemical reaction is the main energy input in the production process, through three main production routes: mercury process, diaphragm process and membrane process. The energy efficiency of these processes is around 63 per cent of the theoretical minium, with significant variation in energy efficiency depending on the process route. In general the membrane process is the most energy efficient of the three processes requiring 8.6–9.2 gigajoules of electricity per tonne of chlorine produced, compared with 10 gigajoules and 11.8 gigajoules of electricity per tonne of chlorine produced for the diaphragm and mercury processes respectively (IEA 2006c).

While Japan uses predominantly membrane processes in chlorine production, the United States uses a diaphragm based process. Clearly, in the short term, converting existing mercury and diaphragm process methods for chlorine production to the membrane process offers significant energy savings potential. Over the longer term, research and development may provide new technological developments that can utilise the hydrogen byproduct. This could further reduce the energy consumption of chlorine manufacturing plants. Alternatively processes that replace hydrogen evolving cathodes with oxygen consuming cathodes could also offer an additional 30 per saving in energy for membrane based processes (IEA 2006c).

cement

Fluidised bed kiln technology is likely to be commercialised only in the medium to long term, enabling energy intensity of cement production to fall toward 2.5 gigajoules a tonne of clinker by 2030 in some regions. By 2050, cement production techniques are expected to advance such that energy intensity approaches the theoretical minimum – about 1.8–2.0 gigajoules a tonne of clinker by 2030 in some regions (ABARE 2006).

Process types and fuel shares differ considerably by region, which explains to a large extent the difference in carbon dioxide emissions per tonne of cement produced. Energy savings can be achieved through energy efficiency improvements through the use of waste fuels.

household energy use and energy efficiency

Household energy use is influenced by a range of factors. These factors include size of dwelling, quality of construction, solar orientation, and shading from adjacent structures or land forms. Other factors influencing household energy use are the type and number of appliances used in the household. These appliances include heating, cooling and ventilation equipment, lighting systems, wet appliances such as clothes driers and dish washers, cooking appliance, domestic hot water services, and various consumer appliances such as televisions and computer related equipment. Energy management systems and meters and metering equipment can also influence the level of energy use. All these factors and the range of household appliance available are discussed in detail in (IEA 2006c). This appendix presents a brief overview of some significant emerging technologies available to the household sector to improve the sector's overall energy efficiency.

heating and cooling

Conventional heating systems for buildings include oil, natural gas or electric heaters. These technologies are considered mature, although considerable efficiency gains can be made through replacing older heating systems with more efficient newer models and by correctly sizing heaters to space heating requirements. For example, primary energy use and greenhouse gas emissions from natural gas heating systems are much lower then electric resistance heating systems as the majority of electric power is supplied from fossil fuel fired power stations with efficiencies of 30–50 per cent. The IEA estimates that replacement of old inefficient and oversized boilers can reduce total energy consumption by 30–35 per cent (IEA 2006c).

Advanced heating systems yet to make a significant penetration into the heating appliance market include heat pumps, active solar, district heating and cooling, thermal energy storage, wood heating and passive solar building designs.

Heat pumps that are capable of both heating and cooling buildings have started to increase their market share over the past decade and are highly likely to contribute to significant energy reductions into the future. The most common type of heat pump are air sourced heat pumps, which use 30–40 per cent less electricity then electric resistance heating. They are also more energy efficient at cooling than conventional air conditioners.

There are three advanced and highly efficient wood heating technologies available: advanced combustion, catalytic stoves, and densified pellet systems (IEA 2006c). These systems have environmental advantages in that they release little smoke pollution. The efficiencies of these systems range between 60–85 per cent.

lighting

The efficiency of different lighting appliances varies considerably, with the range in efficiency of different types of lamps (measured as light output per unit energy input) varying by a factor of ten for available lamp technologies (IEA 2006c). Hence there are significant potential energy savings that can be attained through appropriate lamp selection. These efficiency savings would need to be balanced against any deterioration in lighting quality, as each type of lamp has varying characteristics in relation to amount and distribution of light they deliver, warmup times and colour properties.

The vast majority of lamps used in the household sector are incandescent lamps, the least energy efficient lamp technology available, with an efficiency of 10–15 lumens per watt. Flourescent lamps, with an efficiency of 70–100 lumens per watt, are used to a limited extent in the household sector in most economies, except in Japan and the Philippines where flourescent lamp technology is the dominant technology used for artificial lighting of buildings. The substitution of incandescent lamps with compact flourescent lamps in the household sector offers the greatest potential for near term energy savings for lighting in the household sector.

Over the longer term, new technologies, in particular, semiconductor (light emitting diodes), and metal halide lamps may play a more important role in household lighting in coming decades. For example, the US Department of Energy has set aggressive goals for the development of much more energy efficient solid state lighting technologies by 2015 that, when compared with conventional lighting technologies, are longer lasting and cost competitive. A report prepared for the department on the energy savings potential of solid state lighting in general illumination applications considered two investment scenarios – one where the technology receives a moderate level of national investment of US$50 million a year and an accelerated scenario based on an investment of US$100 million a year (Navigant Consulting 2003). The energy saving associated with the moderate investment scenario is projected to be approximately 114 billion kWh or the equivalent electrical output of about fourteen large power plants (Navigant Consulting 2003).

Building designs that enhance the amount of usable daylight entering buildings have also a large potential to save energy. Passive solar designs also reduce heating energy requirements. In addition, buildings can incorporate a range of architectural features that tunnel light to required areas.

energy management systems and smart meters

Energy management systems are designed to monitor and optimise energy use in buildings. Through incorporating sensors in energy using appliances, these systems are able to save energy that would otherwise have been wasted. A comprehensive energy management system for the building can save 10–20 per cent of annual energy consumption (IEA 2006c).

Smart metering of buildings is also an advanced technology that is being increasingly adopted in OECD countries. Smart metering provides energy consumption data to households in real time, allowing households to adjust energy consumption and take advantage of time based electricity tariffs. Smart meters are also being increasingly deployed in instances where households have become microelectricity generators so that they pay only for net electricity used.

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