INTERNATIONAL ENERGY AGENCY

WORLD ENERGY OUTLOOK 2002

HIGHLIGHTS

INTERNATIONAL ENERGY AGENCY
9, rue de la Fédération,
75739 Paris Cedex 15, France

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six* of the OECD's thirty Member countries. The basic aims of the IEA are:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

**IEA Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), the Republic of Korea (12th December 1996) and Slovakia (28th September 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

FOREWORD

It is always a genuine pleasure to present the *World Energy Outlook*, the IEA's most ambitious and widely read publication. It is particularly gratifying to introduce *WEO 2002*: first, because of the circumstances of its launch and, second, because of the importance of the messages it has to convey.

We decided to release the book, almost two months ahead of the originally planned schedule, at the 2002 Ministerial Meeting of the International Energy Forum, Consumer-Producer Dialogue, in Osaka, Japan. This decision responds to a request from the government of Japan, one of our largest and most dedicated members. It also recognises the value we place on the increasingly confident and fruitful dialogue taking place between oil producers and consumers.

The *World Energy Outlook* is a compendium of thousands of numbers and hundreds of pages of detailed analysis. It is a rich quarry. According to his special interests, the reader may seize upon any one or more of its many facets:

- that world energy demand will grow by two-thirds in the next 30 years;
- that fossil fuels will continue to dominate the energy mix;
- that nearly two-thirds of the growth in energy demand will arise in developing countries;
- that financing the required new energy infrastructure is a huge challenge, depending largely on the framework conditions created by governments;
- that international energy trade will expand dramatically;
- that natural gas demand growth will outpace that of any other fossil fuel, but will itself be outpaced by demand growth for renewables;
- that transport will dominate the growth in oil use;
- that electricity use will grow faster than any other energy end-use;
- that the proportion of the world's population without access to electricity will fall by a third; or, conversely, that 1.4 billion people will still lack access to electricity in 2030;

- that, on the basis of present policies, carbon dioxide emissions from energy use will continue to grow steeply;
- that new technologies will emerge on the energy scene within 30 years; but that it will be much longer before they become dominant.

An Alternative Policy Scenario in this book serves two purposes: it reminds us how the basic picture painted depends on key assumptions, including continuity of present policies; and it indicates how, and to what extent, that picture might be changed by deliberate policy actions. Many changes are possible, for example in policies related to poverty alleviation, energy security, environmental priorities, the nuclear component of supply and many other issues.

The policy mix adopted by governments has to conform to today's standards of sustainable economic development. Economic development cannot be achieved without energy; and it cannot be sustained unless the energy supply is reliable, i.e. secure. But energy production and use also have to be environmentally sustainable – and meet social needs and expectations. Policy-makers have to find the right way to reconcile these requirements. No single element can override the others.

The last chapter of this book deals with energy and poverty. Energy policy-makers alone cannot solve this problem, still less energy analysts. Energy analysts can, however, define the problem properly – the first step towards its solution. That is what we have sought to do. The definition has shocked us. It is totally unacceptable – both morally and economically – that 1.4 billion people should still be without electricity 30 years into this millennium.

This work is published under my authority as Executive Director of the IEA and does not necessarily reflect the views or policies of the IEA Member countries.

Robert Priddle
Executive Director

Comments and questions are welcome and should be addressed as follows:

Fatih Birol
Chief Economist
Head, Economic Analysis Division
International Energy Agency
9, rue de la Fédération
75739 Paris Cedex 15
France

Telephone: (33-1) 4057 6670
Fax: (33-1) 4057 6659
Email: Fatih.Birol@iea.org

World Energy Outlook Series

World Energy Outlook – 1993
World Energy Outlook – 1994
World Energy Outlook – 1995
Oil, Gas & Coal Supply Outlook – 1995
World Energy Outlook – 1996
World Energy Outlook – 1998
World Energy Outlook – 1999 Insights
  Looking at Energy Subsidies: Getting the Prices Right
World Energy Outlook – 2000
World Energy Outlook – 2001 Insights
  Assessing Today's Supplies to Fuel Tomorrow's Growth
World Energy Outlook – 2002
World Energy Outlook – 2003 Insights (forthcoming)
  Global Energy Investment Outlook

TABLE OF CONTENTS

(The Highlights edition contains excerpts from the full text of the *WEO 2002*).

Foreword		3
Acknowledgements		9
Executive Summary		13
Chapter 1	The Analytical Framework	23
2	World Energy Trends	25
	Energy Demand	26
	Energy Production and Trade	37
	Implications for Global CO_2 Emissions	41
	Technological Developments	50
3	The Enery Market Outlook	57
4	OECD North America	59
5	OECD Europe	61
6	OECD Pacific	63
7	China – An In-Depth Study	65
8	Russia	67
9	India	69
10	Brazil	71
11	Indonesia	73
12	The OECD Alternative Policy Scenario	75
13	Energy and Poverty	77

ACKNOWLEDGEMENTS

This study was prepared by the Economic Analysis Division (EAD) of the International Energy Agency (IEA) in co-operation with other divisions of the IEA. The Director of the Long-Term Office, Olivier Appert, provided support and encouragement during the project. The study was designed and managed by Fatih Birol, Head of the Economic Analysis Division. Other members of the EAD who were responsible for bringing this study to completion include: Armando Acosta, Maria Argiri, Amos Bromhead, François Cattier, Laura Cozzi, Lisa Guarrera, Claudia Jones, Hiroyuki Kato, Teresa Malyshev, Trevor Morgan, Scott Sullivan and Michael Taylor.

The following colleagues were also part of the *Outlook* team: Carmen Difiglio, Fridtjof Unander, Sohbet Karbuz, Mike Ting (Energy Technology Policy Division), Miharu Kanai (Oil Market Division), Peter Fraser (Energy Diversification Division) and Kyung-Hwan Toh (Non-Member Countries Division).

Input was provided by other IEA staff, namely: Richard Baron, Xavier Chen, Sylvie Cornot, Sylvie Lambert D'Apote, Ralf Dickel, Mark Hammonds, Lew Fulton, Rebecca Gaghen, Mitsuhide Hoshino, Benoit Lebot, Shin Morita, Isabel Murray, Carlos Ocana, Jonathan Pershing, Riccardo Quercioli, Loretta Ravera, Klaus Rehaag, Rick Sellers and Mike Wittner.

The study also benefited from direct contributions from government bodies, international organisations and energy companies worldwide. These include: the Energy Research Institute of the State Development Planning Commission of China, the European Commission- Directorate General for Transport and Energy, Electricité de France, Eni, the Ministry of Energy of Mexico, the Tata Energy Research Institute of India, the United Nations Food and Agriculture Organization and the World Bank.

This study required a complex analysis of different issues. We asked several experts to comment on the underlying analytical work of this book and to review early drafts of each chapter. Their comments and suggestions were extremely useful. We attempt to acknowledge all those contributions on the following page and apologize if we have inadvertently left anyone off the list.

All errors and omissions are solely the responsibility of the IEA.

Acknowledgement of Experts outside the IEA

African Energy Policy Research Network, Kenya, *Stephen Karakezi*.
Asian Development Bank, Philippines, *Carol Litwin*.
Asia-Pacific Energy Research Centre, Japan, *Yonghun Jung* and *Naoko Doi*.
Australian Greenhouse Gas Office, Australia, *Stephen Berry*.
Cambridge Energy Research Associates, United States of America, *Kevin Lindemer*.
Centre d'Etudes Prospectives et d'Informations Internationales, France, *Nina Kousnetzof*.
CONCAWE, Belgium, *Jean-Francois Larive*.
Constellation Energy, United States of America, *John Paffenbarger*.
Department of Energy, United States of America, *Andy Kydes*, *Bruce Bawks, John Cymbalski, Lynda Doman* and *Crawford Honeycutt*.
Department for International Development, United Kingdom, *Gill Wilkins*.
Directorate General Development, European Commission, Belgium, *Philip Mann*.
Directorate-General for Transport and Energy, European Commission, Belgium, *Manfred Decker, Pietro Menna, Paolo Bertoldi* and *Randall Bowie*.
Electricité de France, France, *François Verneyre* and *Prabodh Porouchottamin*.
Energy Conservation Centre, Japan, *Naohito Okumura*.
Energy Efficient Strategies, Australia, *Lloyd Harrington*.
Energy Research Institute, State Development Planning Commission, China, *Dadi Zhou, Yuan Guo* and *Yufeng Yang*.
Eni, Italy, *Alessandro Lanza*.
German Advisory Council on Global Change to the Federal Government, Germany, *Marc Ringel*.
Institute of Energy Economics, Japan, *Koukichi Ito* and *Yukari Yamashita*.
International Atomic Energy Agency, Austria, *Kee-Yung Nam*.
Jyukankyo Research Institute Inc, Japan, *Naoto Sagawa*.
Kumasi Institute of Technology and Environment, Ghana, *Abeeku Brew-Hammond*.
Lawrence Berkeley National Laboratory, United States of America, *Jonathan Sinton*.
Ministry of Commerce, Industry and Energy, Korea, *Il-Hwan Oh* and *Jae-Joon Kim*.
Ministry of Economy, Trade and Industry, Japan, *Akihiko Inomata*.
Ministry of Energy and Mineral Resources, Indonesia, *Sumiarso Luluk*.

Natural Resources Canada, *Bob Lyman* and *Valentin Konza*.
National Technical University of Athens, Greece, *Leonidas Mantzos*.
Organisation for Economic Co-operation and Development, France, *Ulrich Heimenz, Barrie Stevens, David O'Connor, Jean-Claude Berthelemy, Patrick Love, Riel Miller* and *Celine Kauffmann*.
Organization of Petroleum Exporting Countries, Austria, *Nadir Guerer*.
PW Consulting, United Kingdom, *Paul Wade*.
Simmons & Company, United States of America, *Matt Simmons*.
Swiss Federation Office of Energy, Switzerland, *Jean-Christophe Fuëg*.
Tata Energy Research Institute, India, *Rajendra Pachauri*.
Technical University of Vienna, Austria, *Reinhard Haas* and *Gustav Resch*.
United Nations Environment Program, France, *Lawrence Agbemabiese*.
United Nations Food and Agriculture Organization, Italy, *Gustavo Best, Miguel Trossero and Adrian Whiteman*.
University of Sao Paulo, Brazil, *Edmilson Moutinho dos Santos*.
WEFA Inc., United States of America, *Michael Lynch*.
World Bank, United States of America, *Jamal Saghir, Mohamed Farhandi, Dominique Lallement, Shane Streifel* and *Nouredine Berrah*.
World Coal Institute, *Malcom Keay*.

EXECUTIVE SUMMARY

This edition of the *World Energy Outlook*, which sets out the IEA's latest energy projections to 2030, depicts a future in which energy use continues to grow inexorably, fossil fuels continue to dominate the energy mix and developing countries fast approach OECD countries as the largest consumers of commercial energy. The Earth's energy resources are undoubtedly adequate to meet rising demand for at least the next three decades. But the projections in this *Outlook* raise serious concerns about the security of energy supplies, investment in energy infrastructure, the threat of environmental damage caused by energy production and use and the unequal access of the world's population to modern energy.

Governments will have to take strenuous action in many areas of energy use and supply if these concerns are to be met. The core projections presented here are derived from a Reference Scenario that takes into account only those government polices and measures that had been adopted by mid-2002. A separate Alternative Policy Scenario assesses the impact of a range of new energy and environmental policies that OECD countries are considering adopting as well as of faster deployment of new energy technologies. Both scenarios confirm the extent of the policy challenges facing governments around the world.

A key result of the *Outlook* is that energy trade will expand rapidly. In particular, the major oil- and gas-consuming regions will see their imports grow substantially. This trade will increase mutual dependence among nations. But it will also intensify concerns about the world's vulnerability to energy supply disruptions, as production is increasingly concentrated in a small number of producing countries. Supply security has moved to the top of the energy policy agenda. The governments of oil- and gas-importing countries will need to take a more proactive role in dealing with the energy security risks inherent in fossil-fuel trade. They will need to pay more attention to maintaining the security of international sea-lanes and pipelines. And they will look anew at ways of diversifying their fuels, as well as the geographic sources of those fuels. The OECD Alternative Policy Scenario demonstrates the strong impact that new policies to curb energy demand growth and encourage switching away

from fossil fuels could have on import dependence. Governments and consumers are, nonetheless, likely to continue accepting a degree of risk in return for competitively priced energy supplies.

Necessary expansion of production and supply capacity will call for massive investment at every link in the energy supply chain. Investment of almost $4.2 trillion will be needed for new power generation capacity alone between now and 2030. Mobilising this investment in a timely fashion will require the lowering of regulatory and market barriers and the creation of an attractive investment climate – a daunting task in many countries in the developing world and the former Soviet Union. Most investment will be needed in developing countries, and it is unlikely to materialise without a huge increase in capital inflows from industrialised countries.

Energy-related emissions of carbon dioxide are set to grow slightly faster than energy consumption in the Reference Scenario, despite the policies and measures taken so far. In the Alternative Policy Scenario, however, new policies that many OECD countries are currently considering, together with faster deployment of more efficient and cleaner technologies, would achieve energy savings and promote switching to less carbon-intensive fuels. These developments would eventually stabilise CO_2 emissions in OECD countries, but only towards the end of the *Outlook* period.

More than a quarter of the world's population has no access to electricity, and two-fifths still rely mainly on traditional biomass for their basic energy needs. Although the number of people without power supplies will fall in the coming decades, a projected 1.4 billion people will still be without electricity in 2030. And the number of people using wood, crop residues and animal waste as their main cooking and heating fuels will actually *grow*. To extend electricity supplies to the energy poor and give them better access to other forms of modern energy, stronger government policies and co-ordinated international action will be essential.

Fossil Fuels Will Continue to Dominate Global Energy Use

World energy use will increase steadily through 2030 in the Reference Scenario. Global primary energy demand is projected to increase by 1.7% per year from 2000 to 2030, reaching an annual level of 15.3 billion tonnes of oil equivalent. The increase will be equal to two-thirds of current demand. The projected growth is, nevertheless, slower than growth over the past three decades, which ran at 2.1% per year.

Fossil fuels will remain the primary sources of energy, meeting more than 90% of the increase in demand. Global *oil* demand will rise by about 1.6% per year, from 75 mb/d in 2000 to 120 mb/d in 2030. Almost three-quarters of the increase in demand will come from the transport sector. Oil will remain the fuel of choice in road, sea and air transportation. As a result, there will be a shift in all regions towards light and middle distillate products, such as gasoline and diesel, and away from heavier oil products, used mainly in industry. This shift will be more pronounced in developing countries, which currently have a lower proportion of transportation fuels in their product mix.

Demand for *natural gas* will rise more strongly than for any other fossil fuel. Primary gas consumption will double between now and 2030, and the share of gas in world energy demand will increase from 23% to 28%. New power stations will take over 60% of the increase in gas supplies over the next three decades. Most of these stations will use combined-cycle gas turbine technology, a form of generation favoured for its high energy-conversion efficiency and low capital costs. Gas is also often preferred to coal and oil for its relatively benign environmental effects, especially its lower carbon content.

Consumption of *coal* will also grow, but more slowly than that of oil and gas. China and India together will account for two-thirds of the increase in world coal demand over the projection period. In all regions, coal use will become increasingly concentrated in power generation, where it will remain the dominant fuel. Power-sector coal demand will grow with the expected increase in gas prices. The deployment of advanced technologies will also increase coal's attractiveness as a generating fuel in the long term.

The role of *nuclear power* will decline markedly, because few new reactors will be built and some will be retired. Nuclear production will peak at the end of this decade, then decline gradually. Its share of world primary demand will hold steady at about 7% through 2010, then fall to 5% by 2030. Its share of total electricity generation will fall even faster, from 17% in 2000 to 9% in 2030. Nuclear output will increase in only a few countries, mostly in Asia. The biggest declines in nuclear production are expected to occur in North America and Europe. The prospects for nuclear power are particularly uncertain. Some governments have expressed renewed interest in the nuclear option as a means to reduce emissions and to improve security of supply.

Renewable energy **will play a growing role in the world's primary energy mix.** Hydropower has long been a major source of electricity production. Its share in global primary energy will hold steady, but its share of electricity generation will fall. Non-hydro renewables, taken as a group, will grow faster than any other primary energy source, at an average rate of 3.3% per year over the projection period. Wind power and biomass will grow most rapidly, especially in OECD countries. But non-hydro renewables will still make only a small dent in global energy demand in 2030, because they start from a very low base. OECD countries, many of which have adopted strong measures to promote renewables-based power projects, will account for most of the growth in renewables.

Demand Will Rise Fastest in Developing Countries...

More than 60% of the increase in world primary energy demand between 2000 and 2030 will come from developing countries, especially in Asia. These countries' share of world demand will increase from 30% to 43%. The OECD's share will fall from 58% to 47%. The share of the former Soviet Union and Eastern and Central Europe (the transition economies) will fall slightly, to 10%. The surge in demand in the developing regions results from their rapid economic and population growth. Industrialisation and urbanisation will also boost demand. The replacement of traditional biomass by commercially traded energy will increase recorded demand. Higher consumer prices as energy subsidies are phased out and international prices rise, are not expected to curb energy demand growth.

China, already the world's second-largest energy consumer, will continue to grow in importance on world energy markets as strong economic growth drives up demand and imports. The Chinese economy will remain exceptionally dependent on coal, but the shares of oil, natural gas and nuclear will grow in China's energy mix. Increasing oil- and gas-import needs will make China a strategic buyer on world markets.

...and Transport Uses Will Outstrip All Others

Transport demand, almost entirely for oil, will grow the most rapidly of all end-use sectors, at 2.1% per annum. It will overtake industry in the 2020s as the largest final-use sector. Transport demand will increase everywhere, but most rapidly in the developing countries. OECD transport demand will grow at a slower pace, as markets become more saturated. Consumption in the residential and services sectors will

grow at an average annual rate of 1.7%, slightly faster than in industry, where it will rise by 1.5% per year.

Electricity will grow faster than any other end-use source of energy, by 2.4% per year over the *Outlook* period. World electricity demand will double through 2030, while its share of total final energy consumption will rise from 18% in 2000 to 22% in 2030. The biggest increase in demand will come from developing countries. Electricity use increases most rapidly in the residential sector, especially in developing countries. But the huge difference in per capita electricity consumption between the OECD and developing countries will hardly change over the projection period. The shares of oil and gas in world final consumption will also remain broadly unchanged. Oil products will account for roughly half of final energy use in 2030. The share of coal will drop from 9% to 7%. Coal use will expand in industry, but only in non-OECD countries. It will stagnate in the residential and services sectors.

Fossil Energy Resources Are Ample, but Technologies and Supply Patterns Will Change

The world's energy resources are adequate to meet the projected growth in energy demand. Oil resources are ample, but more reserves will need to be identified in order to meet rising oil demand to 2030. Reserves of natural gas and coal are particularly abundant, while there is no lack of uranium for nuclear power production. The physical potential for renewable energy production is also very large. But the geographical sources of incremental energy supplies will shift over the next three decades, in response to cost, geological and technical factors. In aggregate, almost all the increase in energy production will occur in non-OECD countries, compared to just 60% from 1971 to 2000.

Increased production in the Middle East and the former Soviet Union, which have massive hydrocarbon resources, will meet much of the growth in world oil and gas demand. Most of the projected 60% increase in global oil demand in the next three decades will be met by OPEC producers, particularly those in the Middle East. Output from mature regions such as North America and the North Sea will gradually decline. More oil will become available from Russia and the Caspian region, and this will have major implications for the diversity of supply sources for oil-importing countries.

Global crude oil refining capacity is projected to increase by an average 1.3% a year, reaching 121 mb/d in 2030. The growth of capacity

will be slightly less than that of demand for refined products, because of increased utilisation rates and the elimination of some refinery bottlenecks. Over 80% of new refining capacity will be built outside the OECD, much of it in Asia. Refineries will have to boost their yields of transportation fuels relative to heavier oil products, as well as improve product quality.

Production of natural gas, resources of which are more widely dispersed than oil, will increase in every region other than Europe. The cost of gas production and transportation is likely to rise in many places as low-cost resources close to markets are depleted and supply chains lengthen.

There are abundant coal reserves in most regions. Increases in coal production, however, are likely to be concentrated where extraction, processing and transportation costs are lowest — in South Africa, Australia, China, India, Indonesia, North America and Latin America.

New sources of energy and advanced technologies will emerge during the *Outlook* period. Non-conventional sources of oil, such as oil sands and gas-to-liquids, are set to expand, as their production costs decline. Fuel cells are also projected to make a modest contribution to global energy supply after 2020, mostly in small decentralised power plants. The fuel cells that are expected to achieve commercial viability first will involve the steam reforming of natural gas. Fuel cells in vehicles are expected to become economically attractive only towards the end of the projection period. As a result, they will power only a small fraction of the vehicle fleet in 2030.

International energy trade, almost entirely in fossil fuels, will expand dramatically. Energy trade will more than double between now and 2030. All oil-importing regions – including the three OECD regions – will import more oil, mostly from the Middle East. The increase will be most striking in Asia. The biggest growth markets for natural gas are going to become much more dependent on imports. In absolute terms, Europe will see the biggest increase in gas imports. Cross-border gas pipeline projects will multiply, and trade in liquefied natural gas will surge.

Rising Demand Will Drive Up Carbon Dioxide Emissions

Global energy-related emissions of carbon dioxide will grow slightly more quickly than primary energy demand. They are projected to increase by 1.8% per year from 2000 to 2030 in the Reference Scenario, reaching 38 billion tonnes in 2030. This is 16 billion tonnes, or 70% more than today. Two-thirds of the increase will come in developing countries. Power

generation and transport will account for about three-quarters of new emissions.

The geographical sources of new emissions will shift drastically, from the industrialised countries to the developing world. The developing countries' share of global emissions will jump from 34% now to 47% in 2030, while the OECD's share will drop from 55% to 43%. China alone will contribute a quarter of the increase in CO_2 emissions, or 3.6 billion tonnes, bringing its total emissions to 6.7 billion tonnes per year in 2030. Even then, however, Chinese emissions remain well below those of the United States.

The steep rise in projected emissions in the Reference Scenario illustrates the challenge that most OECD countries face in meeting their commitments under the Kyoto Protocol. Emissions in those OECD countries that signed the Protocol will reach 12.5 billion tonnes in 2010, the middle of the Protocol's target period of 2008-2012. That is 2.8 billion tonnes, or 29%, above the target. Russia, like Central and Eastern Europe, is in a very different situation, with projected emissions considerably *lower* than their commitments. Under the Protocol, lower emissions in Russia, Ukraine and Eastern Europe, known as "hot air", can be sold to countries with emissions over their target. But even "hot air" will not suffice to compensate for over-target emissions in other countries. The overall gap will be about 15% of projected emissions in 2010. If the United States, which does not intend to ratify the Kyoto Protocol, is excluded, the gap falls to 2%.

Carbon sequestration and storage technologies hold out the long-term prospect of enabling fossil fuels to be burned without emitting carbon into the atmosphere. These technologies, however, are unlikely to be deployed on a large scale before 2030. They are at an early stage of development and are very costly. If their costs could be lowered more quickly than assumed here, this would have a major impact on the long-term prospects for energy supply.

Policies under Consideration in the OECD Would Curb Energy Demand and Emissions

In the Alternative Policy Scenario, implementation of policies that are already under consideration in OECD countries would reduce CO_2 emissions by some 2,150 Mt in 2030, or 16% below the Reference Scenario projections described above. This is roughly equal to the total emissions of Germany, the United Kingdom, France and Italy today.

Energy savings achieved by the new policies and measures and by faster deployment of more efficient technologies would be 9% of projected demand in the Reference Scenario in 2030. CO_2 savings would be even bigger, because of the additional impact of fuel switching to less carbon-intensive fuels. Because of the slow pace at which energy capital stock is replaced, CO_2 savings in the early years would be relatively small – only 3% by 2010 and 9% by 2020.

The biggest reduction in CO_2 emissions in the Alternative Policy Scenario would come from power-generation, because of the rapid growth of renewables and savings in electricity demand. OECD governments are currently emphasising renewables and electricity in their long-term plans to curb CO_2 emissions and enhance energy security. Although the three OECD regions would still not individually reach the targets under the Kyoto Protocol, "hot air" could allow the targets to be met.

The Alternative Scenario projections show a marked reduction in import dependence in the major energy-importing regions. In 2030, OECD gas demand would be 260 bcm, or 13%, below the Reference Scenario. The percentage fall in imports would be even greater. The reduction in EU gas imports by 2030 would be greater than total current imports from Russia and Norway. The savings in oil demand would reach 10%, or 4.6 mb/d.

Providing Modern Energy to the World's Poor Will be an Unfinished Task

Some 1.6 billion people have no access to electricity, according to data compiled specially for this study. More than 80% of the people who currently lack electricity access live in South Asia and sub-Saharan Africa. The majority of them live on less than $2 per day, but income is not the only determinant of electricity access. China, with 56% of its people still "poor" by international definition, has managed to supply electricity to the vast majority of its population.

In the absence of major new government initiatives, 1.4 billion people, or 18% of the world's population, will still lack electricity in 2030, despite more widespread prosperity and more advanced technology. The number without electricity in 2030 will be 200 million less than today, even though world population is assumed to rise from 6.1 billion in 2000 to 8.3 billion. Four out of five people without electricity live in rural areas. But the pattern of electricity-deprivation is set

to change, because 95% of the increase in population in the next three decades will occur in urban areas.

Poor people in developing countries rely heavily on traditional biomass – wood, agricultural residues and dung – for their basic energy needs. According to information specifically collected for this study, 2.4 billion people in developing countries use only such fuels for cooking and heating. Many of them suffer from ill-health effects associated with the inefficient use of traditional biomass fuels. Over half of all people relying heavily on biomass live in India and China, but the *proportion* of the population depending on biomass is heaviest in sub-Saharan Africa.

The share of the world's population relying on biomass for cooking and heating is projected to decline in most developing regions, but the *total number of people* will rise. Most of the increase will occur in South Asia and sub-Saharan Africa. Over 2.6 billion people in developing countries will continue to rely on biomass for cooking and heating in 2030. That is an increase of more than 240 million, or 9%. In developing countries, biomass use will still represent over half of residential energy consumption at the end of the *Outlook* period.

Lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create. Experience in China and elsewhere demonstrates how governments can help expand access to modern sources of energy. But electrification and access to modern energy services do not *per se* guarantee poverty alleviation. A variety of energy sources for thermal and mechanical applications are needed to bring productive, income-generating activities to developing countries. Nonetheless, because biomass will continue to dominate energy demand in these countries in the foreseeable future, the development of more efficient biomass technologies is vital for alleviating poverty in rural areas. Renewable energy technologies such as solar, wind and biomass may be cost-effective options for specific off-grid applications, but conventional fuels and established technologies are more likely to be preferred for on-grid capacity expansion.

CHAPTER 1: THE ANALYTICAL FRAMEWORK

HIGHLIGHTS

- Economic growth is the main driver of energy demand. The world's gross domestic product is assumed to grow worldwide by an average 3% per year over the period 2000 to 2030 – a modest slowdown compared to the past three decades. Growth is expected to pick up in 2003 and to remain steady through to 2010, but will then slow progressively over the next two decades as developing countries' economies mature and their population growth slows.
- The world's population is assumed to expand by one-third, from 6 billion in 2000 to 8.2 billion in 2030. The rate of growth will slow gradually from 1.4% in the 1990s to 1% over 2000-2030. Most of the increase in world population will occur in the urban areas of developing countries.
- Crude oil prices are assumed to remain flat until 2010 at around $21 per barrel (in year 2000 dollars) – their average level for the past 15 years. They will then rise steadily to $29 in 2030. Natural gas prices will move more or less in line with oil prices, with regional prices in Europe, the Asia-Pacific region and North America converging to some degree. Coal prices will be flat to 2010 and rise very slowly thereafter.
- Changes in government policies and technological developments, together with macroeconomic conditions and energy prices, are the main sources of uncertainty in the global energy outlook. These factors will affect both the demand for energy services and the rate of investment in supply infrastructure. Uncertainty is inevitably much greater in the last decade of the projection period.

CHAPTER 2: WORLD ENERGY TRENDS

HIGHLIGHTS

- World energy use will continue to increase steadily through 2030 in the Reference Scenario. Fossil fuels will remain the primary sources of energy and will meet more than 90% of the increase in demand to 2030. Among fossil fuels, natural gas will grow fastest, but oil will remain the most important energy source. Renewables will grow in importance, while the share of nuclear power in world energy supply will drop.
- Energy demand will increase most rapidly in developing countries, especially in Asia. The developing countries' share in world demand will increase from just 30% today to more than 40% by 2030. Per capita energy consumption, nonetheless, will remain much lower in developing countries.
- New sources of energy and advanced technologies, including oil sands, gas-to-liquids and fuel cells, will emerge during the *Outlook* period, especially after 2020.
- There will be a pronounced shift in the geographical sources of incremental energy supplies over the next three decades, in response to a combination of cost, geopolitical and technical factors. In aggregate, almost all the increase in energy production will occur in non-OECD countries.
- There will be a major expansion in international energy trade. The regions with most of the world's oil and gas resources, notably the Middle East and Russia, will greatly increase their exports. The OECD and the dynamic Asian economies, which already import large amounts of oil to meet their needs, will increase their oil imports still further. Trade in liquefied natural gas will surge. These developments will push supply security back to the top of the energy policy agenda.
- The expansion in production and supply capacity will call for a huge amount of investment at every stage of the energy supply chain — much of it in developing countries. Mobilising this investment in a timely fashion will require the lowering of regulatory and market barriers.

- Energy-related emissions of carbon dioxide will grow slightly more quickly than total primary energy supply. Power generation and transport will account for about three-quarters of the increase in emissions. More rigorous policies and measures than those so far adopted will be needed for the industrialised countries to meet their emissions reduction commitments under the Kyoto Protocol.

Energy Demand

Primary Energy

Global primary energy demand[1] in the Reference Scenario is projected to increase by 1.7% per year from 2000 to 2030, reaching 15.3 billion tonnes of oil equivalent (Table 2.1). The increase in demand will amount to almost 6.1 billion toe, or two-thirds of current demand. The projected growth is, nevertheless, slower than over the past three decades, when demand grew by 2.1% per year.

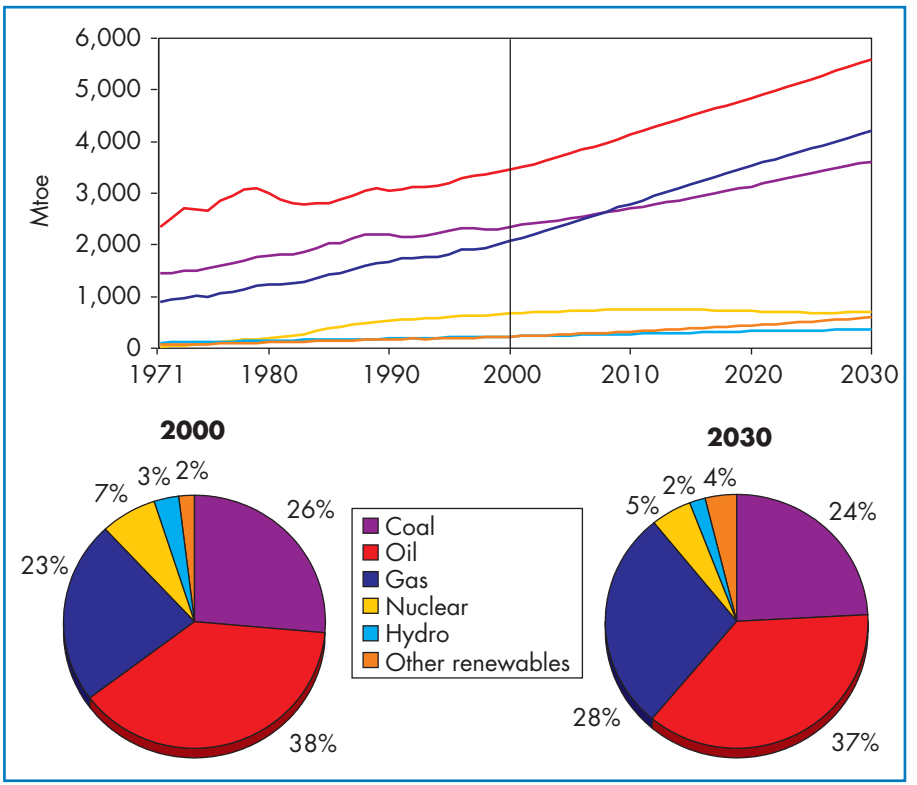
Table 2.1: **World Primary Energy Demand** (Mtoe)

	1971	2000	2010	2030	Average annual growth 2000-2030 (%)
Coal	1,449	2,355	2,702	3,606	1.4
Oil	2,450	3,604	4,272	5,769	1.6
Gas	895	2,085	2,794	4,203	2.4
Nuclear	29	674	753	703	0.1
Hydro	104	228	274	366	1.6
Other renewables	73	233	336	618	3.3
TPES	**4,999**	**9,179**	**11,132**	**15,267**	**1.7**

1. Total primary energy demand is equivalent to total primary energy supply (TPES). The two terms are used interchangeably throughout this *Outlook*. World primary demand includes international marine bunkers, which are excluded from the regional totals. Unless otherwise specified, world demand refers only to commercial energy and excludes biomass in non-OECD countries (see footnote 3). Primary energy refers to energy in its initial form, after production or importation. Some energy is transformed, mainly in refineries, power stations and heat plants. Final consumption refers to consumption in end-use sectors, net of losses in transformation and distribution. See Appendix 2 for detailed definitions.

Fossil fuels will account for just over 90% of the projected increase in world primary demand to 2030 (Figure 2.1). Their *share* in total demand actually increases slightly, from 87% in 2000 to 89% in 2030. **Oil** will remain the single largest fuel in the primary energy mix, even though its share will fall slightly, from 38% to 37%. Oil demand is projected to grow by 1.6% per year, from 75 mb/d in 2000 to 89 mb/d in 2010 and 120 mb/d in 2030. The bulk of the increase will come from the transport sector. No other fuel will seriously challenge oil in road, sea and air transportation during the projection period. In 2030, transportation will absorb 55% of total oil consumption, up from 47% now. Oil will remain a marginal fuel in power generation; a decline in the OECD area will offset a small increase in developing countries. Moderate increases are projected in industrial, residential and commercial oil consumption. Most of these increases will occur in developing countries, where competition from natural gas for space and water heating and for industrial processes will be limited.

Figure 2.1: **World Primary Energy Demand**



Demand for **natural gas** will grow faster than that for any other primary fuel, except for non-hydro renewable energy sources. With annual growth of 2.4% per year, gas will overtake coal just before 2010 as the world's second-largest energy source. Gas consumption will double between 2000 and 2030, and the share of gas in world demand will increase from 23% in 2000 to 28% in 2030, mostly at the expense of coal and nuclear energy. New power stations will account for over 60% of the increase in gas demand over the next three decades. Most of these stations will use combined-cycle gas turbine technology. This form of generation is often preferred to coal-based power technologies and nuclear power because of its high energy-conversion efficiency and low capital costs. Gas is also favoured over coal and oil for its relatively benign environmental effects, especially its lower carbon content. A small but growing share of natural gas demand will come from gas-to-liquids plants and from fuel cells for the production of hydrogen.

Demand for **coal** is projected to rise by 1.4% per year, but coal's share in world primary demand will still fall a little, from 26% in 2000 to 24% in 2030. China and India together account for almost three-quarters of the increase in coal demand in developing countries and two-thirds of the increase in world coal demand. Most of the increase in coal consumption will be in power generation. In OECD countries, an increase in power-sector demand for coal will offset a smaller decline in coal use in end-use sectors. The industrial, residential and commercial sectors in the transition economies and in developing countries will burn more coal, but power generation accounts for the bulk of the increase in overall coal demand in both groups.

The role of **nuclear power** will decline markedly over the *Outlook* period, because it is assumed that few new reactors will be built and several will be retired.[2] Nuclear production will peak in the next few years, then decline gradually. Its share of world primary demand will hold steady at about 7% through 2010, then fall to 5% by 2030. Nuclear output will increase in only a few countries, mostly in Asia. The biggest falls in nuclear production are expected to occur in North America and Europe.

2. Investment in new nuclear plants is projected to be limited on competitiveness grounds and because many countries have restrictions on new construction. Should governments enact strong policy measures to facilitate investment in nuclear plants, then the share of nuclear power in electricity generation could be significantly larger than projected here. Plant construction and extensions to the lifetimes of existing plants will depend critically on political decisions as well as economic factors.

Hydropower has long been a major source of electricity production, but its relative importance is set to diminish. Much of the OECD's low-cost hydro-electric resources have already been exploited and environmental concerns in developing countries will discourage further large-scale projects there. World hydropower production will grow slowly, by an average 1.6% a year through 2030, but its share of primary demand will remain almost constant at 2.5% over the *Outlook* period. The developing countries will account for most of the increase in hydropower production. Its share in global electricity generation will drop, from 17% to 14%.

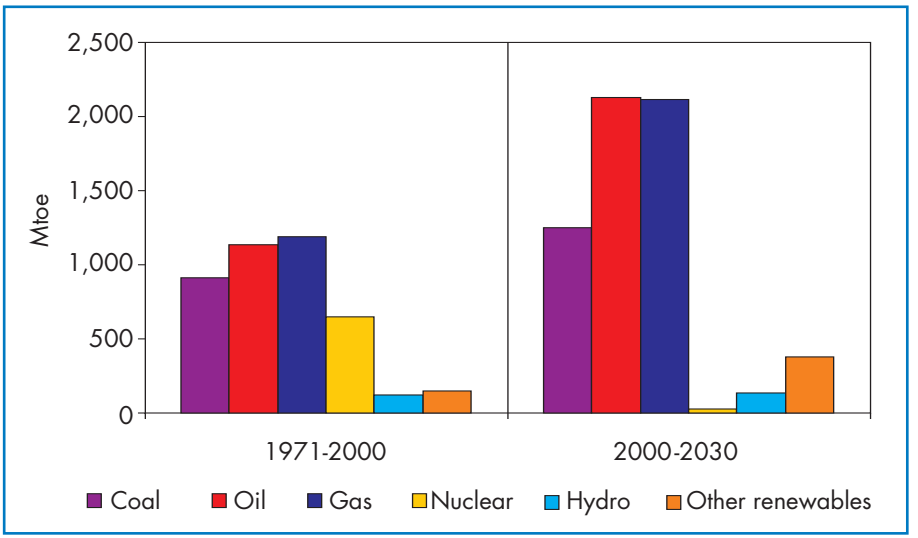
Box 2.1: Non-commercial Biomass Use in Developing Countries

Non-commercial biomass represents one-quarter of total energy demand in developing countries. Biomass use in these countries is excepted to rise over the *Outlook* period, from 891 Mtoe in 2000 to 1,019 Mtoe in 2030, but its *share* in their total primary energy demand will fall. Demand will be stronger in the first decade, rising by 0.8% per year, but will slow to 0.1% per year in the last decade. The use of biomass, particularly wood products, in developing countries is likely to become more commercial over the projection period. Biomass will be increasingly traded in markets similar to those in many OECD countries today. The energy demand projections in this *Outlook* do not include traditional biomass use in developing countries. They are provided separately in the tables in Part D.

Other renewables[3], taken as a group, will grow faster than any other energy source, at an average rate of 3.3% per year over the projection period. But they will still make only a small dent in global energy demand in 2030, because they start from a very low base. Most of the increase in renewables use will be in the power sector. Their share in total generation will grow from 1.6% in 2000 to 4.4% in 2030. In absolute terms, the

3. This category includes geothermal, solar, wind, tidal and wave energy. It also includes biomass for OECD countries only. In this study, the term biomass includes traditional biomass energy, gas and liquid fuels from organic material, industrial waste and municipal waste. For developing countries, separate projections for traditional biomass use (wood, crop residues and animal waste), much of which is non-commercial, are included in the Annex to Chapter 13. Biomass is commercially traded in many developing countries, especially in South America. But IEA statistics do not distinguish between commercial and non-commercial biomass use. See Chapter 13 for a discussion of the link between biomass use and poverty in developing countries.

Figure 2.2: **Increase in World Primary Energy Demand by Fuel**



increase in the use of renewables will be much bigger in OECD countries, mainly because many of them have adopted strong promotional measures. Among non-hydro renewables, wind power and biomass will grow most rapidly, especially in OECD countries.

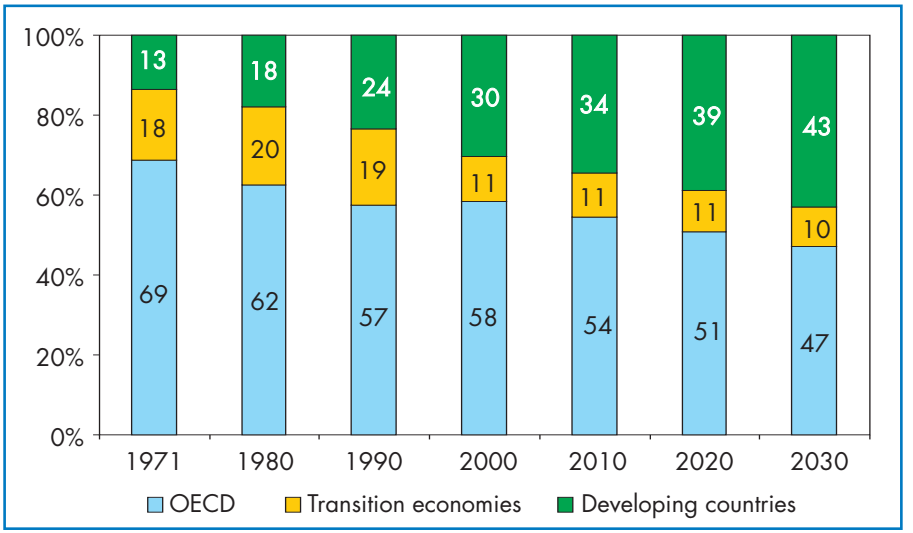
Regional Outlook

More than 60% of the increase in world primary energy demand between 2000 and 2030 will come from the developing countries (Figure 2.3). OECD countries will account for 30% and the transition economies for the remaining 8%. The OECD's share of world demand will decline, from 58% in 2000 to 47% in 2030, while that of the developing countries will increase, from 30% to 43%. The transition economies' share will fall slightly.

The increase in the share of the developing regions in world energy demand results from their rapid economic and population growth. Industrialisation, urbanisation and the replacement of non-commercial biomass by commercial fuels also boost demand. Increases in prices to final consumers, a result of the gradual reduction in subsidies and rising international prices, are not expected to curb energy demand growth in developing countries.

The developing regions will account for 29 mb/d of the 45-mb/d increase in global oil demand between 2000 and 2030. The developing

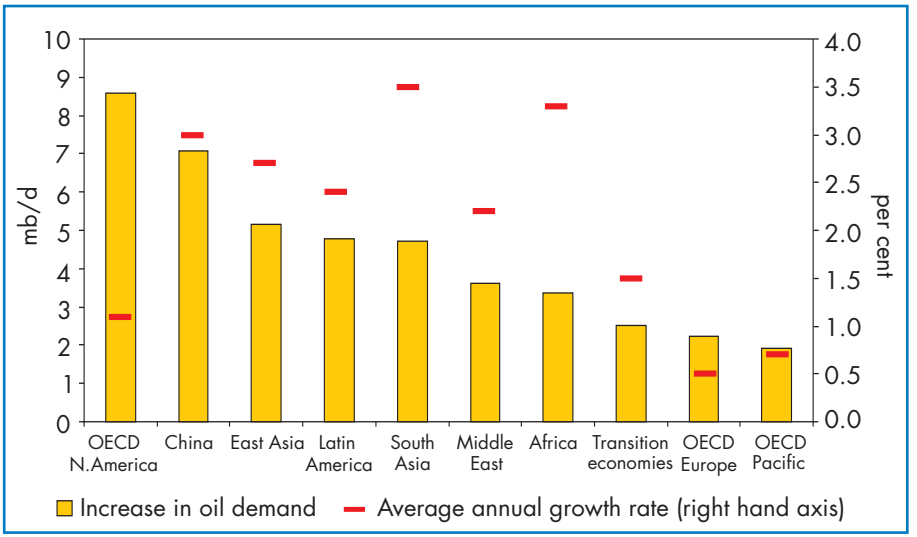
Figure 2.3: **Regional Shares in World Primary Energy Demand**



Asian countries will take the largest share. Oil demand in China will rise by 7 mb/d over the projection period to 12 mb/d in 2030. Other East Asian countries' oil demand will more than double, to 9.4 mb/d. Oil consumption in OECD North America will rise strongly too, from 22 mb/d in 2000 to almost 31 mb/d in 2030. Demand in other OECD regions will increase only modestly (Figure 2.4). North America remains by far the largest single market for oil.

Natural gas demand will grow strongly and the share of gas in the primary fuel mix will increase in every region. In volume terms, gas demand will increase the most in OECD North America and OECD Europe. But the fastest rates of growth will occur in China and South Asia, where gas consumption is currently very low. Coal demand will increase most in China and India, which have large, low-cost resources. Although coal's market share will decline a little, it will continue to dominate the fuel mix in those two countries. By 2030, China and India will account for 45% of total world coal demand, up from 35% in 2000. Nuclear power will fall in OECD North America, in OECD Europe and in the transition economies. It will increase in all other regions, but only marginally in most cases. The biggest increases in nuclear power production will occur in Japan, Korea and developing Asian countries.

Figure 2.4: **Increase in Primary Oil Demand by Region, 2000-2030**



Energy Intensity

Energy intensity, measured as total primary energy use per unit of gross domestic product, is projected to decline in all regions. From 2000 to 2030, global energy intensity will fall by 1.2% per year. Intensity will fall most quickly in the non-OECD regions, largely because of improved energy efficiency[4] and structural economic changes towards lighter industry. The average rate of decline in energy intensity in these regions will accelerate from past trends. The transition economies, in particular, will become much less energy-intensive as more energy-efficient technologies are introduced, wasteful energy practices are tackled and energy prices are reformed. The shift to services is so far advanced in the OECD countries that their energy intensity is set to fall more slowly than in the past (Figure 2.5).

Energy-related Services

Energy is consumed in order to provide various services. Demand for energy is, in economists' parlance, a "derived demand". Identifying the drivers of demand for these services improves our understanding of long-term trends in energy consumption. These energy-related services are:

- mobility (non-electrical energy used in all forms of transport);

4. For a discussion of the link between energy intensity and energy efficiency and the role of pricing, see IEA (2000).

Figure 2.5: **Primary Energy Intensity by Region**

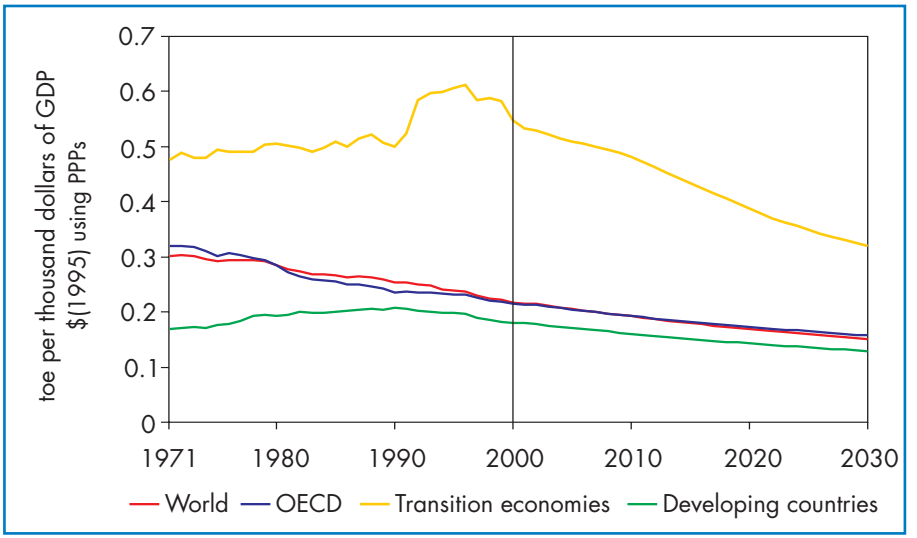
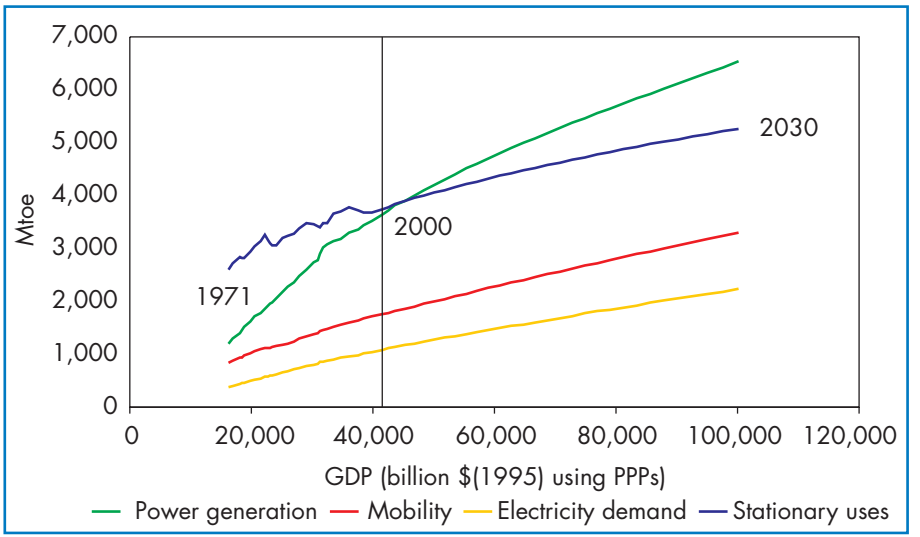


Figure 2.6: **World Energy-Related Services, 1971-2030**



- stationary uses (fossil fuels used to provide heat in houses, commercial buildings and industrial processes);
- electrical uses (final electricity consumption in the residential, services, industrial and other end-use sectors); and
- fuel inputs to power generation (an intermediate energy-related service).

World energy use for both mobility and electrical services will grow along with GDP, but at a slightly slower rate (Figure 2.6). Over the last thirty years, electrical services expanded more rapidly than GDP, and mobility slightly less. Fuel inputs to power generation will also continue to rise with electrical services, but at a decelerating rate. Thermal losses in generation are expected to decline gradually as more efficient technologies, notably combined-cycle gas turbine plants, are deployed. Stationary uses of energy are less closely linked to economic growth than the other energy-related services. Having fluctuated around a moderately rising trend for the last two decades, demand for stationary uses is projected to grow slowly over the *Outlook* period, partly because of saturation effects and heavy industry's declining share of GDP in the OECD. Energy demand for stationary uses will grow more rapidly relative to GDP outside the OECD, partly because of strong growth in energy-intensive industries like iron and steel and chemicals.

Final Energy

Aggregate energy demand in final-use sectors (industry, transport, residential, services, agriculture and non-energy uses) is projected to grow by 1.7% per year from 2000 to 2030 – the same rate as primary energy demand. Transport demand will grow the most rapidly, at 2.1% per annum, overtaking industry in the 2020s as the largest final-use sector. Transport demand will increase everywhere, most rapidly in the developing countries, at 3.6% per year. OECD transport demand will grow at a more leisurely 1.4%, because of saturation effects. Residential and services consumption will grow at an average annual rate of 1.7%, slightly faster than industrial demand, which will rise by 1.5% per year. Information and communication technology introduces a major uncertainty into the prospects for final energy use (Box 2.2).

Among all end-use sources of energy, electricity is projected to grow most rapidly worldwide, by 2.4% per year from 2000 to 2030 (Table 2.2). Electricity consumption will double over that period, while its share in total final energy consumption will rise from 18% to 22%. Electricity use will expand most rapidly in developing countries, by 4.1% per year, as the number of people with access to electricity and per capita consumption increase. Demand will increase by 2% in the transition economies and by 1.5% in the OECD.

Box 2.2: The Implications of Information and Communication Technology on Energy Demand

The growth of information and communication technology is affecting energy demand in many ways, including:

- *Income effects*: To the extent that the production and use of ICT boost overall economic growth, they raise the overall demand for energy services.
- *Price effects*: ICT will increase productivity in various sectors by different amounts. These differences will alter the relative price of goods and services, thereby affecting patterns of energy use.
- *Structural effects*: Because these new technologies are used mostly in services, the service sector's share of GDP is growing faster than might otherwise have been the case. This phenomenon helps lower energy intensity, since services require less energy input per unit of output than does industry.
- *Efficiency gains*: Business-to-business and business-to-customer electronic commerce can reduce energy use by improving operational efficiency, partly through better supply chain and inventory management. Web-based retailing reduces the need for large inventories and shop space. If the overall demand for commercial premises falls, energy consumption in the construction sector would be lower. Part of the effect of improved efficiency on energy use would be offset by the impact of higher income (the "rebound effect").
- *Fuel mix effects*: ICT equipment is powered exclusively by electricity, and this tends to raise electricity's share in final energy use.

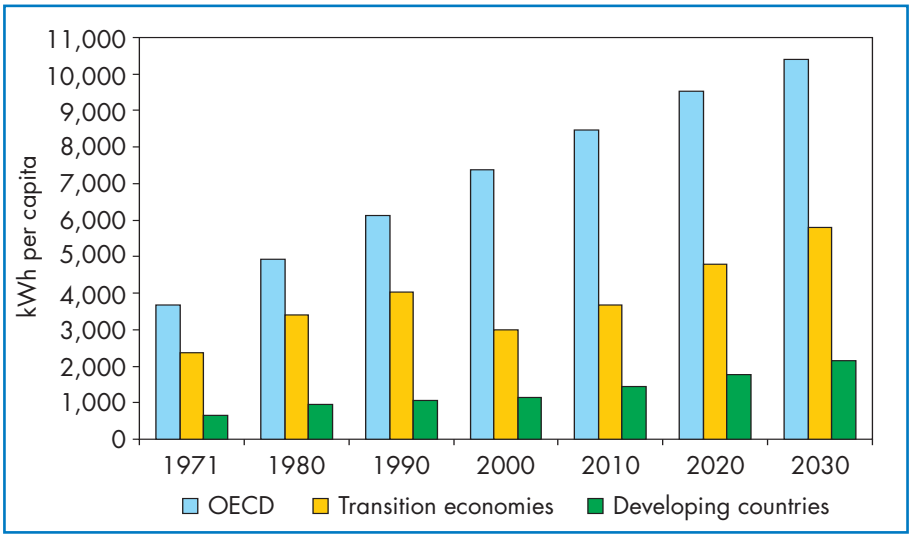
Recent studies give no clear indication of what the net effect of ICT on overall energy demand might be. But they suggest that the impact varies with structural factors within different countries, such as the relative size of the service sector.[5]

5. The IEA is continuing its quantitative analysis of this issue and is upgrading its models to capture the impact of ICT on energy-demand patterns and trends. The proceedings of the IEA workshop on the future impact of ICT on the energy system can be found at www.worldenergyoutlook.org.

Table 2.2: **World Total Final Consumption** (Mtoe)

	1971	2000	2010	2030	Average annual growth 2000-2030 (%)
Coal	630	554	592	664	0.6
Oil	1,890	2,943	3,545	4,956	1.8
Gas	604	1,112	1,333	1,790	1.6
Electricity	377	1,088	1,419	2,235	2.4
Heat	68	247	260	285	0.5
Renewables	66	86	106	150	1.8
Total final consumption	**3,634**	**6,032**	**7,254**	**10,080**	**1.7**

Figure 2.7: **Per Capita Electricity Consumption**



The share of electricity in total final consumption in developing countries catches up with that of the OECD by 2030. This is partly because continued electrification in the poorest developing countriesmore than keeps pace with population growth (see Chapter 13). In part, it is also because the share of natural gas in final uses is much lower in developing countries than in the OECD countries. Electricity's *apparent* share in these countries is also boosted by the fact that biomass is not included in our figures for total final consumption. However, per capita electricity

consumption of people with access to electricity in developing countries remains well below that of OECD countries in 2030 (Figure 2.7).

The share of coal in world final consumption will drop from 9% to 7%. Coal use will expand in industry, but only in non-OECD countries, and will stagnate in the residential and services sectors. The shares of oil and gas in world final consumption will hardly change over the projection period. Oil products will account for roughly half of final energy use and gas for 18%. Oil demand will grow by 1.8% per year, with almost three-quarters of the increase coming from transport. The share of transport in incremental oil demand is over 90% in the OECD.

Energy Production and Trade

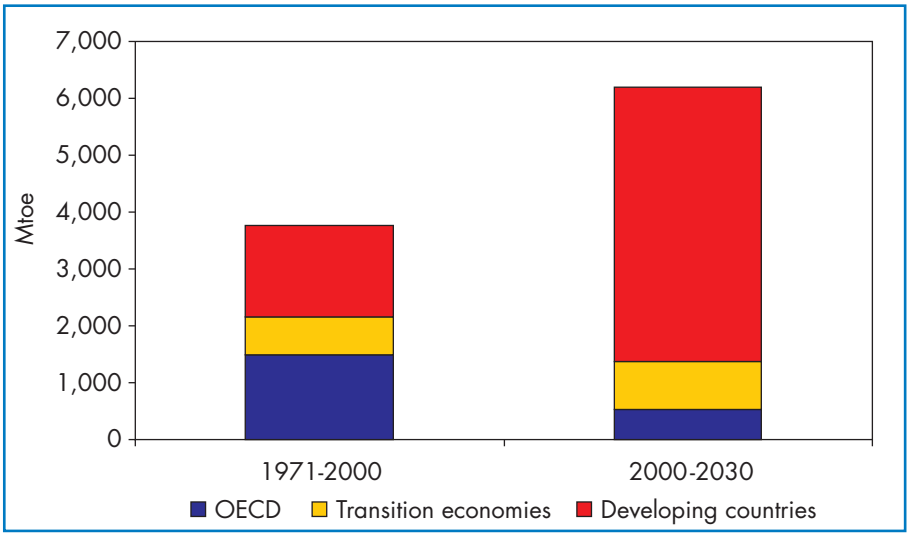
Resources and Production Outlook

The world's energy resources are adequate to meet the projected growth in energy demand. Global oil supplies will be ample at least until 2030, although additional probable and possible reserves will need to be "proved up" in order to meet rising demand. Unconventional oil will probably carve out a larger share of global oil supplies. Reserves of natural gas and coal are particularly abundant, while there is no lack of uranium for nuclear power production through 2030. Renewable energy sources are also plentiful.

There will be a pronounced shift in the geographical sources of incremental energy supplies over the next three decades, in response to a combination of cost, geopolitical and technical factors. Their aggregate effect will be that almost all the increase in energy production will occur in non-OECD countries, compared to just 60% from 1971 to 2000 (Figure 2.8).

Increases in production in the Middle East and the former Soviet Union, which have massive hydrocarbon resources, are expected to meet much of the growth in world oil and gas demand. Latin America, especially Venezuela and Brazil, and Africa will also raise output of both oil and gas. Oil production will decline almost everywhere else. Production of natural gas, resources of which are more widely dispersed than oil, will increase in every region other than Europe. Although there are abundant coal reserves in most regions, increases in coal production are likely to be concentrated where extraction, processing and transportation costs are lowest. Coal production is likely to grow most rapidly in South Africa, Australia, China,

Figure 2.8: **Increase in World Primary Energy Production**



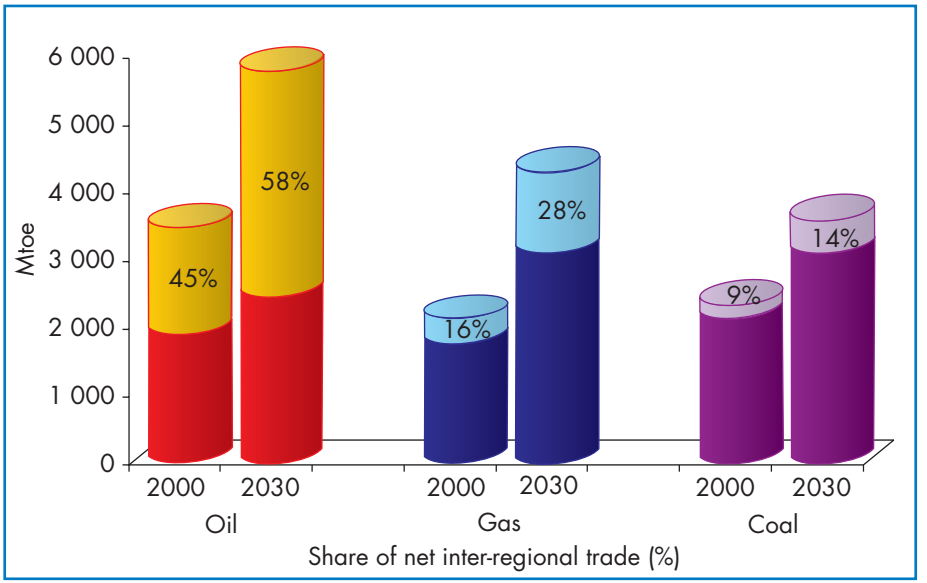
Indonesia, North America and Latin America. The production prospects for each fuel are discussed in more detail in Chapter 3.

Implications for International Energy Trade

International trade in energy will expand in both absolute terms and as a share of production to accommodate the mismatch between the location of demand and that of production (Figure 2.9). Growing trade, almost entirely in fossil fuels, will have major geopolitical implications. Dependence on Middle East oil will continue to grow in the net oil-importing regions, essentially the three OECD regions and some parts of Asia. This development will increase mutual dependence, but will also intensify concerns about the world's vulnerability to a price shock induced by a supply disruption. Maintaining the security of international sea-lanes and pipelines will become more important as oil supply chains lengthen.

Increasing dependence on imports of natural gas in Europe, North America and other regions will heighten those concerns. The disruption in liquefied natural gas supplies from Indonesia in 2001, caused by civil unrest, demonstrated the risks of relying on imports of gas from politically sensitive regions. On the other hand, the expected expansion of international LNG trade could alleviate some of the risks of long-distance supply chains if it leads to more diversified supplies. Increased short-term trading will also make LNG supplies more flexible.

Figure 2.9: **Share of Net Inter-Regional Trade in World Fossil-Fuel Supply**



Note: Total international trade is even larger because of trade between countries within each *WEO* region and re-exports.

The governments of oil- and gas-importing countries are expected to take a more proactive role in dealing with the energy security risks in fossil fuel trade. They are likely to work on improving relations with energy suppliers. They will also step up measures to deal with short-term supply emergencies or price shocks. Governments and end-users are, nonetheless, likely to set a limit on the premium they are prepared to pay in order to enhance the security of energy supplies.

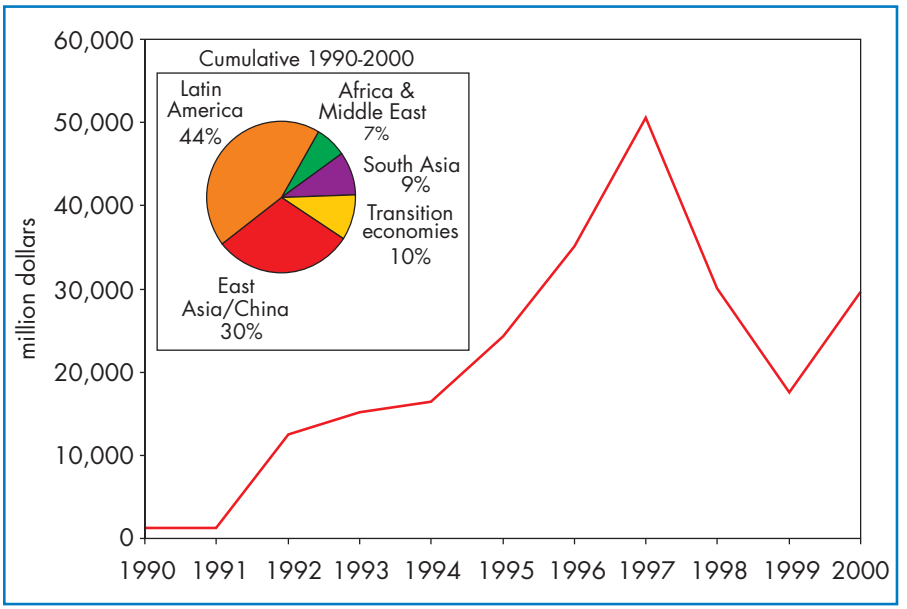
Implications for Investment

The projected increase in production and supply capacity will call for a huge amount of investment at every link in the energy supply chain.[6] For example, the Reference Scenario projections of power generating capacity call for cumulative investment of $2,100 billion in developing countries and $300 billion in the transition economies (see Chapter 3). Financing

6. The IEA is undertaking a major study of energy investment, to be published in 2003 *(WEO 2003 Insights*: *Global Energy Investment Outlook*). It will quantify the amount of investment that will be needed globally to meet the increase in demand projected in this *Outlook* and will consider project-financing issues.

the building of new energy infrastructure will be a major challenge. Most of the required investment is needed in developing countries. This will call for a huge increase in capital inflows from industrialised countries. Private foreign investment in energy projects (excluding upstream oil and gas) in developing countries and transition economies boomed in the early to mid-1990s, peaking at nearly $51 billion in 1997. Investment slumped in the wake of the 1997-1998 economic crisis in emerging market economies to less than $18 billion in 1999, but recovered to some $30 billion in 2000 (Figure 2.10).[7]

Figure 2.10: **Private Foreign Energy Investment in Developing Countries and Transition Economies***



* Not including oil and gas exploration and production.
Source: World Bank's Private Participation in Infrastructure (PPI) database.

Mobilising this investment in a timely fashion will require the lowering of regulatory and market barriers. Most major oil and gas producers in Africa, the Middle East and Latin America, recognise the need for foreign involvement. Algeria, Egypt, Libya and Nigeria, for example,

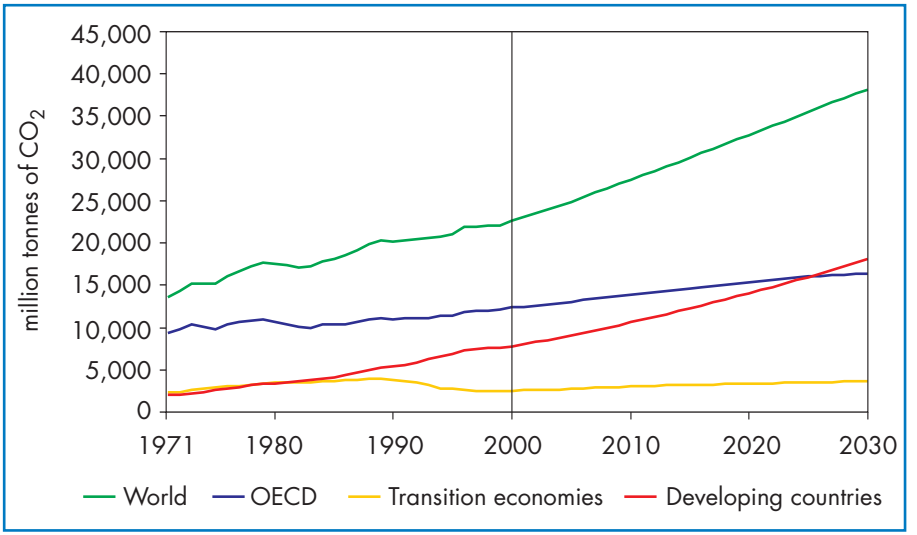
7. See also Saghir (2002). Overseas development assistance from industrialised countries to developing countries declined in the1990s.

have changed their upstream policies and practices to attract joint-venture investment by international oil companies. Since 1992, Venezuela has sought private investment in the oil and gas sectors. Saudi Arabia has recently started to open its upstream gas sector to foreign companies. Key coal producers, including China and India, will need to attract huge amounts of capital to meet their medium-term production targets. Many developing countries are liberalising and restructuring their electricity industries in order to attract private domestic and foreign investment. Improvements in the way state-owned energy companies are run are also needed in many countries. A lack of transparency and consistency, together with weak judicial systems, have encouraged vested interests and led to corruption, fraud, theft and money laundering in some cases. These problems raise production costs and discourage private investment.

Implications for Global CO_2 Emissions

The Reference Scenario projections for energy demand imply that worldwide carbon-dioxide emissions will increase by 1.8% per year from 2000 to 2030.[8] They will reach 38 billion tonnes in 2030. This is 16 billion tonnes, or 70%, above current levels. Two-thirds of the increase will come from developing countries. By 2010, energy-related CO_2 emissions will be 36% higher than in 1990.

Figure 2.11: **Energy-Related CO_2 Emissions by Region**



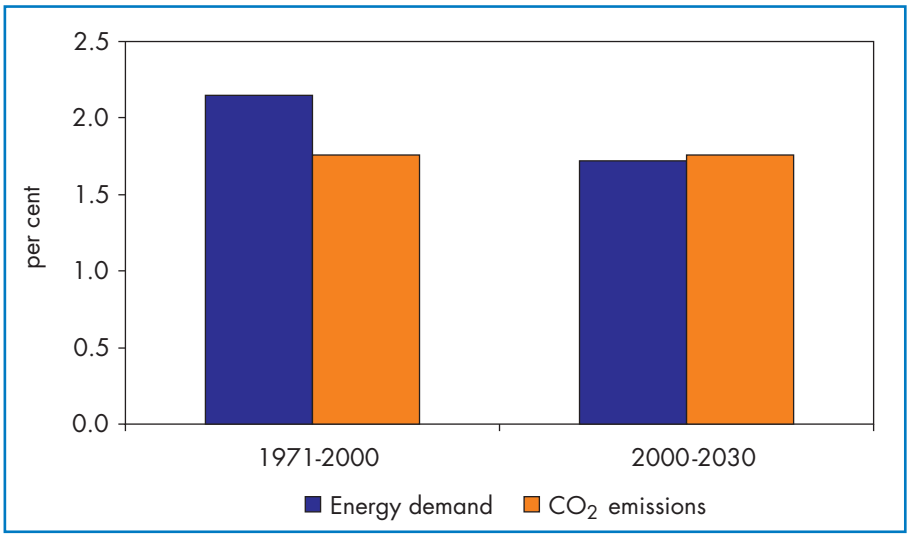
8. Detailed projections of energy-related CO_2 emissions can be found in Part D.

The geographical structure of new emissions will change drastically over the *Outlook* period (Figure 2.11). Historically, OECD countries have been the largest emitters of greenhouse gases. In 2000, they produced 55% of global carbon emissions; developing countries accounted for 34% and the transition economies for the remaining 11%. By 2030, developing countries will have become the most heavily emitting region, with 47% of global emissions. The OECD will account for 43% and the transition economies for 10%. OECD emissions will increase by 4 billion tonnes between 2000 and 2030. China's emissions alone will grow by 3.6 billion tonnes.

Over the past three decades, the mining and burning of coal accounted for 40% of the *increase* in world CO_2 emissions, while oil produced 31% and gas 29%. In the coming three decades, oil will produce 37% of new energy-related carbon emissions and coal 32%. As a result, coal's share in *total* emissions will fall by three percentage points, to 36% in 2030. The share of gas will rise to 25%.

The trend in the relationship between *total* CO_2 emissions and primary energy demand will reverse over the projection period. Over the past three decades, carbon emissions grew by 1.8% a year, but were outstripped by energy demand, which grew at 2.1%. Over the next 30 years, on present policies, emissions will continue to increase at 1.8%

Figure 2.12: **Average Annual Growth Rates in World Energy Demand and CO_2 Emissions**



per year, while energy demand growth will be only 1.7% per year (Figure 2.12). As a result, the average carbon content of energy — CO_2 emissions per unit of aggregate primary energy consumption — will increase slightly, from 2.47 tonnes per toe to 2.50 tonnes. In 1971, the average carbon content was 2.7. The main cause of this reversal will be the declining share of nuclear power and hydroelectricity in the global energy mix. Non-hydro renewables will be increasingly used and technology will increase the efficiency of energy systems, but neither of these developments will make up for the increase in fossil fuel use required to replace nuclear energy and hydropower.

Box 2.3: **Trends in Carbon Intensity**

Carbon intensity is typically defined as the amount of CO_2 emitted per unit of GDP. From 1997 to 2000, global emissions grew by 1.1% a year, while the global economy grew, on average, by 3.5%. Consequently, carbon intensity *fell* by 2.2% annually over the period (Figure 2.13).

The bulk of this reduction can be attributed to China, which, according to official statistics, achieved a spectacular 7.4% decrease in carbon intensity. This was led by an annual decrease of 2.2% in CO_2 emissions[9] from coal. Improved energy efficiency in transition economies helped to lower global carbon intensity. So did the shift from industry to services in the OECD.

Carbon intensity will drop throughout the world over the next three decades, but not fast enough to avoid a net rise in CO_2 emissions. The decline in carbon intensity will be driven mainly by a global shift from manufacturing to the service sector, technological advances and by fuel switching.

Over the projection period, the greatest improvement will be in the transition economies, as old and inefficient capital stock is replaced and as natural gas substitutes for coal and oil in power generation. The economic recovery in Russia is expected to continue, and the country's carbon intensity, which is now six times as high as Japan's and three times as high as China's, will decline by more than 2% annually to 2030. China and India are also expected to see rapid improvements in their carbon intensity over the projection period.

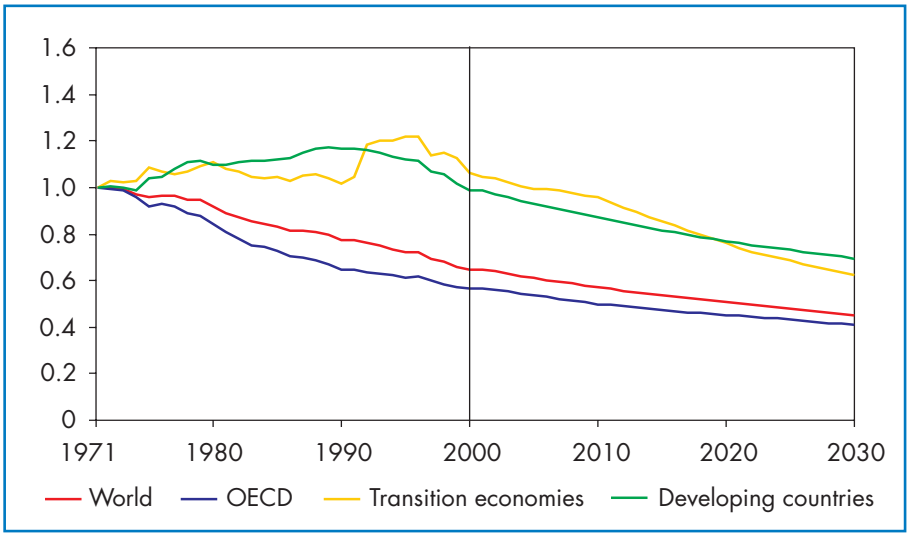
9. In 1997, China's CO_2 emissions from coal accounted for 30% of the world emissions from coal. This figure is now down to 27%. See Chapter 7 for more details on Chinese coal consumption figures.

Regional Trends in CO_2 Emissions

The Reference Scenario sees CO_2 emissions in OECD countries reaching 16.4 billion tonnes in 2030. The largest increase will come in North America[10], where emissions will reach 9.1 billion tonnes, an increase of 1.1% per year, or 71% over 1990. In the OECD Pacific region, CO_2 emissions will grow by 0.9% annually, from 1.9 billion tonnes in 2000 to 2.5 billion tonnes in 2030, or 67% over 1990. Emissions in OECD Europe will rise by 23% over the projection period, a far more moderate rate than in North America and Pacific. This relatively successful performance can be attributed to the increased use of renewable energy and natural gas.

Among developing countries, China's emissions will increase by far the most. This will be due to China's strong economic growth, its rapid increase in electricity demand and its continuing heavy reliance on coal. Chinese emissions will more than double, from 3.1 billion tonnes in 2000 to 6.7 billion tonnes in 2030. China will contribute one-quarter of the increase in global CO_2 emissions.

Figure 2.13: **Carbon Intensity by Region**
(Index, 1971=1)



10. See Chapters 4 to 11 for a more comprehensive description of regional trends and Chapter 12 on the OECD Alternative Policy Scenario for an assessment of the potential for reducing CO_2 emissions in the OECD.

Coal will also be used to fuel new power generating capacity in other developing Asian countries and will account for a large proportion of the increase in their CO_2 emissions. In India, CO_2 emissions will grow by 3% a year, as most new power stations built in the period to 2030 will run on coal. Indian transport-related emissions will account for a quarter of the national increase in total emissions. In East Asia, emissions will rise from 1.1 billion tonnes in 2000 to 2.8 billion tonnes in 2030. Half of the increase will come from the power sector and more than a quarter from transportation.

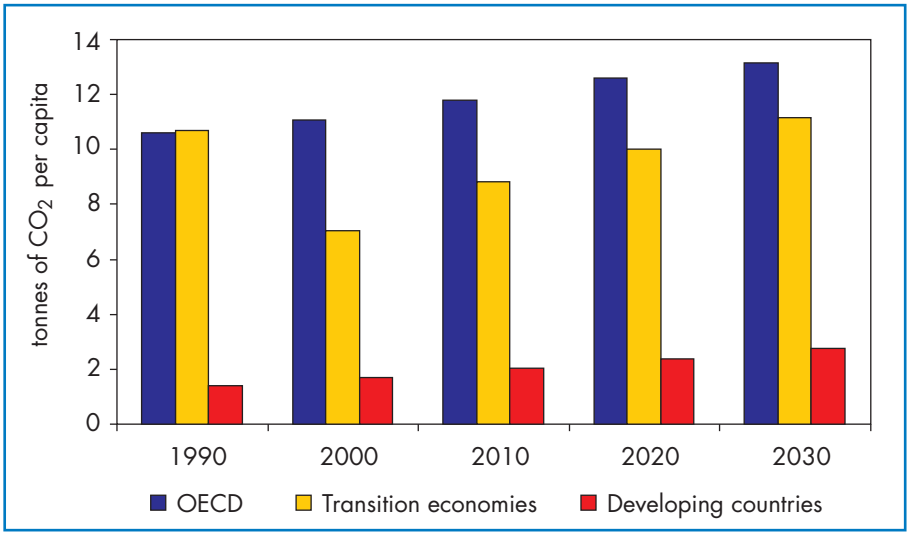
CO_2 emissions in Latin America will rise by 3% per year over the projection period as a result of a rapid rise in fossil fuel demand. Emissions from power plants will rise faster than electricity generation, as the continent's hydropower potential is used up and it starts tapping its large natural gas reserves. Latin America's total emissions will rise from 0.9 billion tonnes in 2000 to 2.1 billion tonnes in 2030. Africa's contribution to global CO_2 emissions will remain small over the next three decades, as large segments of the population will continue to live without commercial energy.

Trends in Per-capita CO_2 Emissions

Per capita CO_2 emissions worldwide are expected to grow by 0.7% per year over the next three decades. They will reach 4.7 tonnes in 2030, up from 3.8 tonnes in 2000. Regional differences will remain very large. Per capita emissions will rise considerably in China, from 2.4 tonnes to 4.5 tonnes in 2030. In India, they will rise from 0.9 tonnes to 1.6 tonnes. They will more than double in Indonesia. In Africa, emissions per head are now very low at 0.9 tonnes per capita and will rise by half to 1.3 tonnes in 2030. Despite these increases, the OECD and the transition economies will still have much higher per capita emissions in 2030: 13 tonnes in the OECD and 11 tonnes in the transition economies (Figure 2.14).

Urbanisation will play a significant role in the growth in per capita emissions. Seven of the world's ten most populated cities are in developing countries. More than half the entire population of the developing world will live in urban areas in 2030, up from 40% today. Per capita emissions in cities are often two or three times those at the national level, because urban dwellers have better access to commercial energy than the rural population. They also have better access to transport services.

Figure 2.14: **Per Capita CO_2 Emissions**



CO_2 Emissions by Sector

Power generation will contribute almost half the increase in global emissions between 2000 and 2030 (Table 2.3). Transport will account for more than a quarter. The residential, commercial and industrial sectors will account for the rest.

Table 2.3: **Increase in CO_2 Emissions by Sector** (million tonnes of CO_2)

	OECD		Transition economies		Developing countries		World	
	1990-2010	2000-2030	1990-2010	2000-2030	1990-2010	2000-2030	1990-2010	2000-2030
Power generation	1,373	1,800	44	341	2,870	5,360	4,287	7,500
Industry	11	211	-309	341	739	1,298	440	1,850
Transport	1,175	1,655	-52	242	1,040	2,313	2,163	4,210
Other*	244	363	-428	234	620	1,365	436	1,962
Total increase	**2,803**	**4,028**	**-746**	**1,158**	**5,268**	**10,336**	**7,325**	**15,522**

*Agriculture, commercial, public services, residential and other non-specified energy uses.

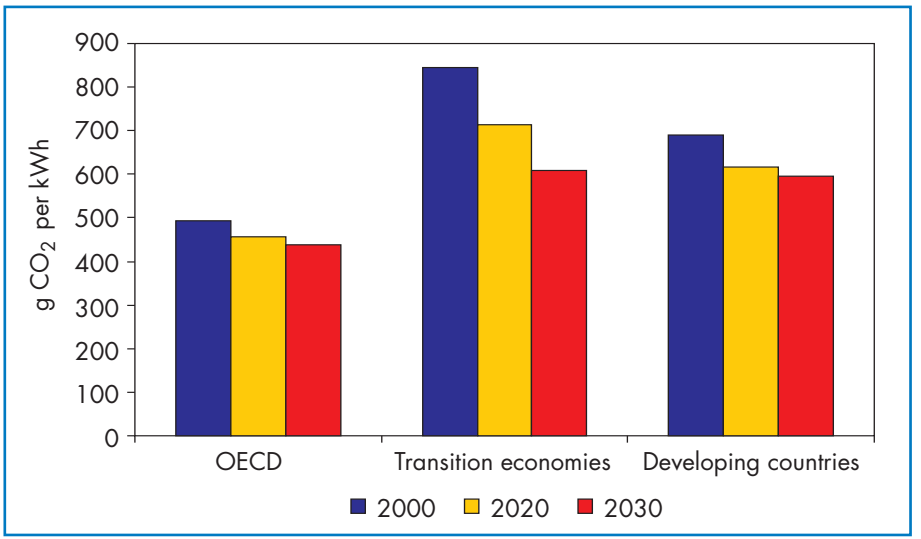
Power Generation Emissions

Electricity generation will be a growing source of total CO_2 emissions, rising from 40% of total CO_2 emissions in 2000 to 43% in 2030. The Reference Scenario sees the power sector becoming more dependent on fossil fuels over the projection period. It projects CO_2 emissions growing in closer synchrony with electricity generation than in the past. The expected increase of thermal efficiency in power generation, the greater use of natural gas and the growing use of non-hydro renewables will moderate the growth in emissions to some extent, but not decisively.

Developing countries will account for almost three-quarters of the incremental CO_2 emissions from power generation. Coal-fired power plants in these countries will still account for *more than half* the global increase in power generation CO_2 emissions in the next three decades. Power sector emissions in the OECD and in the transition economies will rise much more slowly, because renewables and natural gas will take market share from coal.

Emissions per unit of electricity are expected to decrease over time, but regional differences will remain high even on this point (Figure 2.15). The efficiency of power plants in the transition economies and in the developing countries could improve more quickly than projected here, but only if modern technology is deployed soon on a larger scale.

Figure 2.15: **CO_2 Emissions per kWh of Electricity Generated**



Note: Emissions in this chart include those from heat production. This overestimates somewhat the emissions per unit of electricity shown above.

Transport Emissions

Rising oil consumption in the transport sector, mainly by cars and trucks, is the second major source of increased CO_2 emissions in the Reference Scenario, after power generation. Global transport sector emissions are projected to rise by more than 85% from 2000 to 2030. In 2030, transport will account for roughly a quarter of global energy-related emissions, up from 21% in 2000. More than half of the increase is expected to take place in the developing countries. OECD countries will contribute about 40%. Most of the increase in the OECD will come from road transport.

The rapid increase of CO_2 emissions in developing countries can be largely attributed to a projected increase in both vehicle ownership and freight transport. The increase is particularly strong in Asia where per capita car and motorbike ownership is still low compared with the global average. In 2000, China averaged 12 vehicles per 1,000 persons; and India 8.4. In the United States and Canada, the figure is close to 700. Road freight is also expected to increase sharply. Because the developing Asian countries hold nearly half the world's population, an increase in road transport would have a huge impact on global emission levels. These projections make it clear that Asian countries will have to make enormous investments in their road infrastructure. They will also face a host of local environmental problems, especially traffic congestion and air pollution.

CO_2 Emissions Projections and the Kyoto Protocol

The CO_2 emissions projections in this *Outlook* have particular relevance to the commitments of developed countries ("Annex B") under the Kyoto Protocol.[11] Table 2.4 provides a regional breakdown of emissions projections for these countries and the gap remaining between them and the Kyoto commitments in both percentage and absolute terms. These figures reflect only energy-related CO_2 emissions, while the Protocol covers six gases and the contribution of forest sinks.

11. The 1997 Kyoto Protocol calls for industrialised countries listed in its Annex B to reduce their greenhouse gas emissions by an amount that would bring the total to at least 5% on average below 1990 levels over the 2008 to 2012 period. Annex B includes all OECD countries except Korea, Mexico and Turkey. To take effect, the Kyoto Protocol must be ratified by at least 55 nations, which together must represent at least 55% of developed countries' carbon dioxide emissions. By June 2002, 74 countries, including all European Union countries, had ratified the Protocol. These countries account for 36% of emissions.

Table 2.4: **CO_2 Emissions from Energy and Targets in Annex B Countries, 2010** (million tonnes of CO_2)

	Emission targets for 2010	WEO emissions 2010	Gap* (%)	Gap (Mt CO_2)
OECD Annex B countries**	9,662	12,457	28.9	2,795
Russia	2,212	1,829	-17.3	-383
Ukraine and Eastern Europe	1,188	711	-40.2	-477
Total	13,062	14,997	14.8	1,935

* The difference between target emissions and projected emissions as a percentage of the target emissions. In other words, it is the extent to which projected emissions exceed targets.
** This total covers all OECD countries with commitments under the Kyoto Protocol (Annex B countries). Turkey, Mexico and Korea are the only OECD countries not included in Annex B. However, Australia and the United States announced in 2001 that they would not ratify the agreement.
Note: The emission targets for 2010 differ from those in *WEO 2000* because emissions data for 1990 have been revised.

The steep rise in emissions in the Reference Scenario highlights the challenge that the Kyoto Protocol represents for most OECD countries, particularly in North America and the Pacific. For OECD European countries, energy-related CO_2 emissions are projected to be about 8% above target by 2010. Emissions in all OECD countries with commitments under the Protocol will be 12.5 billion tonnes, that is 2.8 billion tonnes, or 29%, above their target.

Russia, like Central and Eastern Europe, is in a very different situation, with projected emissions considerably *lower* than their commitments. Russia's emissions will be some 0.4 billion tonnes below its commitments. Emissions in Ukraine, with other Central and Eastern European countries, will also be below their commitments, by about 0.5 billion tonnes[12]. The Protocol allows for countries to offset mutually their emission commitments through a trading system. But lower emissions in Russia, Ukraine and Eastern Europe ("hot air") will not be enough to compensate for higher emissions in other Annex B countries. The overall gap will amount to about 15% of projected emissions in 2010. However, the gap is only 2% if the United States is excluded.

12. The Russian gap was 600 million tonnes of CO_2 in *WEO 2000*. The reduction in this edition comes mainly from revisions to data for the base year, 1990, as well as more favourable assumptions about GDP growth.

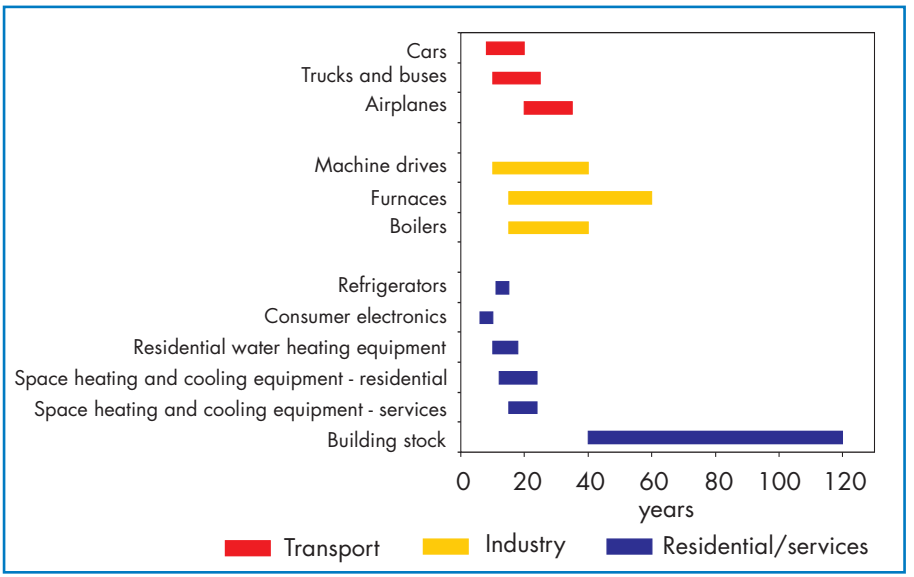
Technological Developments

Throughout the projection period, the supply and consumption of energy is expected to take place using broadly the same technologies that are already in use or are currently available. Technological advances are assumed to take place, but these will be incremental rather than revolutionary. Some technologies that exist today will become commercial during the next three decades. There will be a gradual shift towards less polluting technologies, particularly those based on renewable energy in power generation. Technological breakthroughs may well take place in some areas, but predicting their timing and magnitude is impossible. Government support of energy research and development will continue to play a key role in the pursuit of technological progress.

Demand-side Technologies

The Reference Scenario assumes that the efficiency of energy use – the amount of energy needed to provide a given amount of energy service – will continue to improve at a pace similar to that of the past three decades. Because most of the energy-using capital stock has a long life, technological advances can affect the average energy efficiency of equipment and appliances in use only very gradually (Figure 2.16).

Figure 2.16: **Lifetimes of Energy Capital Stock**



In the transport sector, vehicle fuel efficiency will continue to improve in most regions. Voluntary agreements with car manufacturers and standards are expected to lead to improvements in the fuel efficiency of new passenger vehicles of 30% between 2000 and 2030 in the European Union and 20% in Japan, Australia and New Zealand. However, the energy saved will be partly offset by an increase in the total number of kilometres driven. No improvement is expected in the United States and Canada, because technical advances in vehicle fuel efficiency will be offset by an increase in car size, weight and the number of appliances in each car. No changes in efficiency standards, known as CAFE in the United States, are assumed in the Reference Scenario. In all regions, hybrid vehicles that run on both conventional fuels and electric batteries will gain a foothold in the vehicle fleet. Fuel-cell vehicles are not expected to penetrate the fleet to a significant degree before 2030.

In stationary energy uses in the industrial, commercial and residential sectors, progressive improvements in energy efficiency are assumed to occur as a result of ongoing technological advances. For example, the growing deployment of integrated building designs, which incorporate efficient lighting, heating and cooling systems, will reduce energy consumption per square metre of office space in new office buildings. Energy efficiency standards and labelling programmes already in place will continue to encourage more efficient equipment and appliances in these sectors. However, these efficiency improvements will be very gradual, because of the slow rate of replacement of energy-capital stock, especially buildings.

Supply-side Technologies

Improvements will continue to be made in supply-side technologies, including cost reductions. Efforts will continue on reducing the cost of finding and producing oil and gas. Key new technologies in this area, such as advanced seismic techniques, will improve the identification of reservoir characteristics. Better drilling and production engineering can also be expected. Further advances will be made in deep-water technologies and enhanced oil recovery techniques. Major advances are also expected in high-pressure gas pipelines, LNG processing and gas-to-liquids production technology. The use of advanced coal-mining technology, together with an increase in the scale of individual mine projects, will continue to drive productivity gains and lower the cost of coal extraction and preparation.

Considerable progress is expected to be made in improving the fuel-conversion efficiency of existing power generation technologies. There will also be reductions in the capital costs of emerging fossil fuel- and renewables-based power technologies. The average efficiency of new combined-cycle gas turbine plants is assumed to rise from 55% in 2000 to 62% by 2030 in OECD countries. Coal-fired integrated gasification combined-cycle (IGCC) plants are expected to become competitive with gas-fired by the middle of the projection period. But this technology will come under renewed competitive pressure later from renewables. The average efficiency of IGCC technology is assumed to reach 52% in 2030 compared to 43% at present. The higher efficiencies of new gas- and coal-fired plant will push up the average efficiency of all plants in operation over the projection period (Figure 2.17). No breakthrough in nuclear power technology is assumed before 2030.

The capital costs of renewable energy technologies are expected to fall substantially, making electricity production from renewables increasingly competitive over the projection period. Capital and overall generating costs will continue to vary widely across regions according to local factors. Further reductions are expected in the generating costs of wind power from larger turbines, which improve performance, and from higher efficiencies in biomass conversion. The projected rate and extent of the decline in costs for each source are shown in Figure 2.18, but the figures are very uncertain.

Figure 2.17: **Average World Power Generation Efficiency by Fuel**

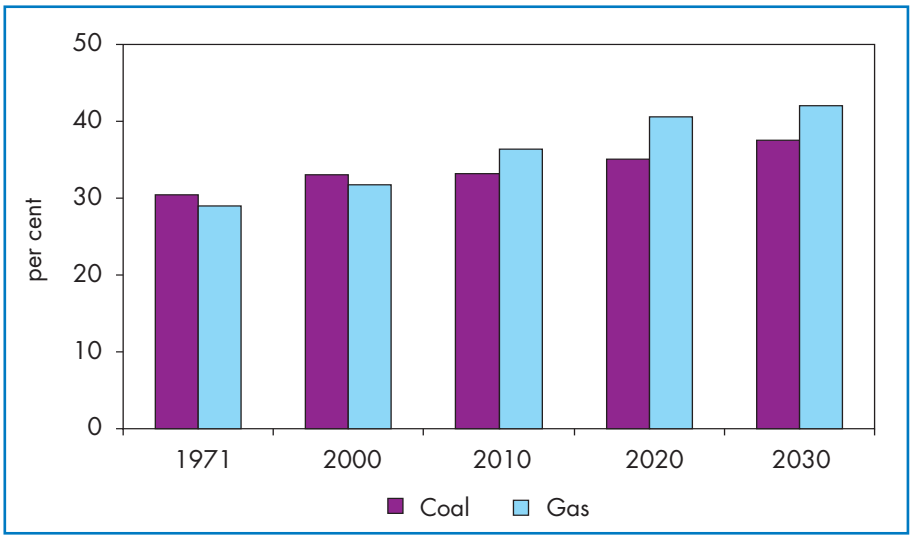
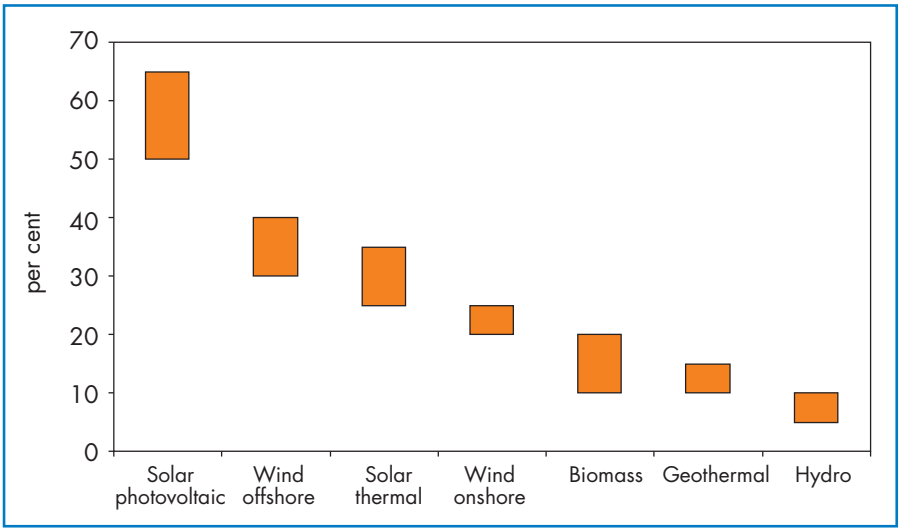


Figure 2.18: **Reductions in Capital Costs of Renewable Energy Technologies, 2000-2030**



Fuel cells are projected to make a contribution to global energy supply after 2020, mostly in stationary applications. Fuel cells are battery-like devices that convert oxygen and hydrogen into electricity. Hydrogen can be extracted from hydrocarbon fuels using a process known as reforming, and from water by electrolysis. The fuel cells that are expected to achieve commercial viability first will involve the reforming of natural gas inside the fuel cell or in a separate device. Production of hydrogen from coal and biomass or using electrolysis is not likely to be economically feasible before 2030. Almost all the fuel cells in use by 2030 will be for distributed power generation. Fuel cells are expected to become competitive in distributed generation when capital costs fall below $1,000/kW, just over a quarter of current costs, and their efficiency approaches 60% (compared to less than 40% now). Fuel cells in vehicles are expected to become economically attractive only towards the end of the projection period. As a result, they will account for only a small fraction of the vehicle fleet in 2030.[13]

Carbon sequestration and storage technologies are not expected to be deployed on a large scale before 2030. It is by no means clear how soon these technologies could become economically and technically feasible. If their costs could be lowered sufficiently, they would increase the

13. See Barreto *et al.* (2002) for a long term scenario describing the role of hydrogen in the global energy system.

attractiveness of fossil fuels over renewable energy sources. This would revolutionise long-term prospects for energy supply (Box 2.4).

Box 2.4: **Capture and Storage of CO_2 from Fossil Fuels**

Technologies are being developed to capture the carbon dioxide emitted from fossil fuel-fired power plants and to store it underground in geological structures or in the ocean. The most common approach to capturing CO_2 exploits a reaction with amines to "scrub" the CO_2 from the gas stream. This process, already used in the chemical industry, could potentially be adapted to capture CO_2 from existing gas- and coal-fired power plants after the combustion process. The cost is projected to be approximately $30 to $50 per tonne of CO_2. Another approach under development aims to separate CO_2 pre-combustion.

Capturing the CO_2 is only part of the problem; the gas must then be transported and stored permanently. A number of options for storage have been identified:

- Reinjecting CO_2 into oil fields may lead to enhanced oil recovery, and this would offset part of the cost of dealing with the gas. Global storage potential in oil-producing reservoirs has been estimated at about 130 billion tonnes. Another 900 billion tonnes could be stored in depleted gas fields. But storing CO_2 in depleted oil or gas fields raises some new issues. Filling a reservoir with CO_2 would increase pressure. Injecting CO_2 into deep coal-beds could enhance methane production. Global coal-bed storage capacity is estimated at about 15 billion tonnes.
- Highly saline underground reservoirs could provide an enormous additional storage capacity, although they offer no offsetting revenue potential. Since 1996, a million tonnes of CO_2 separated from the gas produced from the Sleipner West field in the Norwegian sector of the North Sea has been injected annually into a saline undersea reservoir. Seismic monitoring suggests that the CO_2 is effectively trapped below the impermeable geological cap overlying the reservoir. However more experiments in injecting CO_2 into aquifers are needed to gain a better understanding of the process and

potential risks. Saline reservoirs throughout the world might store as much as 10 trillion tonnes of CO_2, equivalent to more than ten times the total energy-related emissions projected for the next 30 years.

- Disposal of CO_2 in the ocean might be the solution for regions with no depleted oil and gas fields or aquifers. The oceans potentially could store *all* the carbon in known fossil fuel reserves. Tests are underway on a small scale to assess the behaviour of CO_2 dissolved in the ocean and its impact on the ocean fauna.

It is not yet clear how geological and oceanic systems will react to large-scale injection of CO_2. Key technologies for capture and geological storage of CO_2 have all been tested on an experimental or pilot basis, but they will be deployed on a commercial scale only if the risks and costs can be sufficiently reduced and a market value is placed on reducing CO_2 emissions.

CHAPTER 3:
THE ENERGY MARKET OUTLOOK

HIGHLIGHTS

- Most of the projected 60% increase in global oil demand in the next three decades will be met by OPEC producers, particularly those in the Middle East. Output from mature regions such as North America and the North Sea will decline. Resources of conventional crude oil are adequate to meet demand to 2030, but the role of non-conventional oil, such as oil sands and gas-to-liquids, is likely to expand, especially after 2020. All the oil-importing regions – including the three OECD regions – will import more oil. The increase in volume terms will be greatest in Asia.
- Over 80% of new crude oil refining capacity will be built outside the OECD, which will become more reliant on refined product imports. Crude oil refineries will have to boost yields of transportation fuels relative to heavier oil products, as well as improve product quality. The share of refined products in total oil trade will increase.
- Demand for natural gas is projected to rise more strongly than for any other fossil fuel, driven mainly by the power sector. Gas demand will reach 5 trillion cubic metres in 2030, double that of 2000. The biggest markets for gas will become much more dependent on imports. In absolute terms, Europe and North America will see the biggest increase in imports. Russia and the Middle East-Africa will be the biggest exporters in 2030.
- Demand for coal will also grow, but more slowly than for oil and gas. China and India together will account for two-thirds of the increase in world coal demand over the projection period. In all regions, coal will be increasingly concentrated in power generation.
- World electricity demand is projected to double between 2000 and 2030, with most growth in developing countries. The next three decades will see a pronounced shift to gas in the fuel mix for power generation. But coal will still be the main generating

fuel in 2030. Non-hydro renewables – notably wind power and biomass – will also grow rapidly, especially in OECD countries, where renewable energy receives active government support.

- To meet the projected increases in electricity demand, total investment of $4.2 trillion will be needed from 2000 to 2030 in power generating capacity alone. Just over half this amount will be needed in developing countries. In many countries, it is uncertain that enough financing will be forthcoming.

CHAPTER 4:
OECD NORTH AMERICA

HIGHLIGHTS

- The Reference Scenario shows an average annual rate of growth of 1% in primary energy demand in the United States and Canada. Demand will rise more slowly after 2010, due to a gradual slowdown in economic growth, saturation effects and rising energy prices.
- The United States and Canada will remain heavily dependent on oil, which they use predominantly for road and air transport. But gas will grow in relative importance, because many new power plants will be gas-fired. The supply of renewables expands rapidly, though their share in primary supply will still be less than 10% in 2030.
- If the US and Canadian governments take no new action to rein in demand and boost production, net imports of oil will continue to rise, reaching 15.5 mb/d, or 57% of the region's consumption, in 2030. A large and growing share of these additional imports will come from OPEC countries. Gas imports, predominantly liquefied natural gas, will grow from very low levels now to around 30% of demand in 2030, as domestic supplies tighten and gas prices rise. New policies to promote switching to other fuels or curb gas demand, not taken into account here, would reduce gas-import dependence.
- New policy initiatives, including those recently proposed under the US National Energy Policy, could alter demand and supply trends substantially, as well as the outlook for energy-related carbon-dioxide emissions. In the absence of any new actions, emissions would rise by 1% per year from 2000 to 2030.
- Mexico's primary energy use will expand by 2.5% per year over the *Outlook* period, more than twice as fast as demand in the US and Canada. Oil will still dominate the fuel mix, but there will be a substantial increase in the use of gas. The development of Mexico's abundant energy resources and the expansion of its supply infrastructure hinge on the continuation of the government's reform programme.

CHAPTER 5: OECD EUROPE

HIGHLIGHTS

- Primary energy demand in the European Union will rise by 0.7% a year to 2030, underpinned by GDP growth of 1.9%. Demand will rise slightly more rapidly in the rest of OECD Europe. In both sub-regions, oil and gas will still dominate the fuel mix, while the share of coal will continue to fall.
- The power sector will account for a growing share of EU primary energy use. Most of the projected increase in capacity will be gas-fired, but non-hydro renewables will grow quickly from a low base. The importance of nuclear energy will diminish as few new plants are built and some older ones are retired.
- The European Union will need to import progressively more fossil fuels, given coal, oil and gas production declines. The share of net imports in the Union's oil supply will climb from 73% in 2000 to 92% in 2030. Net imports of gas will also expand, from 44% now to 81% of total EU gas supply in 2030.
- Carbon dioxide emissions will rise at the same rate as primary energy use. Emissions will rise more quickly than in the past three decades. Without major new initiatives, the European Union will need to rely heavily on flexibility mechanisms in order to achieve its greenhouse gas emission target under the Kyoto Protocol.
- The possible introduction of new policies to curb rising energy imports and CO_2 emissions is a critical uncertainty in Europe's energy outlook.

CHAPTER 6: OECD PACIFIC

HIGHLIGHTS

- Primary energy demand in Japan, Australia and New Zealand will grow by 0.8% per annum from 2000 to 2030. But growth in demand decelerates over the period due to a gradual slowdown in economic growth, a continued shift to less energy-intensive activities, stagnating population and saturation effects in the transport, residential and services sectors.
- In this group of countries, the shares of natural gas, nuclear energy and renewable energy sources will grow at the expense of coal and oil. This trend results partly from government measures to promote less carbon-intensive fuels. Nonetheless, their oil import dependence will rise steeply, reaching 92% in 2030.
- Energy-related carbon dioxide emissions will increase broadly in line with primary energy use for the first decade of the *Outlook* period. As a result, these countries will not meet their Kyoto commitments unless they adopt vigorous new policies.
- Korea's primary energy demand will grow by 2.3% per annum over the projection period – much slower than in the past thirty years. Oil will continue to dominate Korea's fuel mix, but the shares of gas and nuclear energy will expand further. With virtually no indigenous fossil-fuel resources, Korea's share of international energy trade will continue to expand.

CHAPTER 7:
CHINA – AN IN-DEPTH STUDY

HIGHLIGHTS

- China, the world's second-largest consumer of primary energy, is a key player in world energy markets, accounting for more than 10% of the world's total primary energy demand. It will continue to be an energy giant in the coming decades as strong economic growth drives up energy demand and imports.
- The Chinese economy is very dependent on coal, of which it has large resources that are cheap to extract. Coal will continue to be a dominant fuel, but the shares of oil, natural gas and nuclear in the primary fuel mix will grow.
- Until the 1990s, the Chinese oil market was largely isolated from the rest of the world, because China produced enough oil to meet its own needs. But oil demand is outstripping production. Imports of crude oil and refined products are growing fast. By 2030, net oil imports are projected to reach almost 10 mb/d – more than 8% of world oil demand. Imports will also have to meet 30% of the country's natural gas needs in 2030. These trends will make China a strategic buyer on world energy markets.
- The investment in energy supply infrastructure needed to meet projected growth in Chinese demand is enormous. Some of the needed funds will come from foreign private investors, but it is not clear whether such capital can be mobilised in a timely fashion. More than $800 billion will be needed for new power generating capacity alone over the next three decades.
- China is already a major contributor to global carbon dioxide emissions. Its share in world emissions is currently 14% and will be even larger by 2030, unless the government takes action. The power sector is responsible for a large part of the increase in emissions, but the share of transport also grows fast.

CHAPTER 8: RUSSIA

HIGHLIGHTS

- Russia will play an increasingly important role in world oil and gas markets over the *Outlook* period. The country is already the world's largest gas exporter and the second-largest exporter of oil and oil products, after Saudi Arabia. Russian exports are set to grow strongly in the next few years.
- The development of Russia's vast resources will be crucial to the energy security of countries within and without the OECD. The current reform process must persist in order for Russia to exploit its huge resource base over the medium term.
- If Russia is to consolidate its role as the largest gas exporter to Europe, it must secure the investment to develop new fields in less accessible areas and to build more pipelines. Russia is also expected to start exporting gas to markets in the Far East, including China.
- The *Outlook* projects that Russia will need to invest some $157 billion in new generating capacity over the next thirty years. The government would like to free up more natural gas for export, but gas has several advantages over other fuels, including higher efficiency, reduced environmental damage and ample supply.
- Russia is the third-largest energy consumer in the world, after the United States and China. Despite a decade of declining energy consumption, Russia's energy intensity is still quite high. Energy efficiency improvements in power generation and end-uses will come about only if current price reforms continue.
- The *Outlook* projects that Russia's energy-related carbon dioxide emissions in 2010 will be 17% below what they were in 1990. If an emissions-trading system is established under the Kyoto Protocol, Russia will be in a position to sell its surplus emissions.

CHAPTER 9: INDIA

HIGHLIGHTS

- India will become an increasingly important player on world energy markets as continued rapid expansion of the population and strong economic growth drive up energy demand. Primary energy supply will rise by an average 3.1% per year between 2000 and 2030. Final demand for oil, gas and electricity will increase rapidly.
- With limited domestic resources, India will have to import more oil and gas. Coal imports will probably increase too, as demand shifts to higher quality grades that can be acquired more cheaply abroad. The country's oil import dependence will increase sharply, from 65% in 2000 to 94% in 2030.
- The prospects for electricity supply are uncertain, given the industry's severe financial difficulties, the result of decades of underpricing and poor management. Massive investment is needed to boost India's generating capacity, and to improve and expand its transmission and distribution networks to meet growing demand. India's electrification rate is projected to grow, but hundreds of millions of people will still be without electricity in 2030.
- Natural gas could play a much bigger role in India's energy mix in the future. But financial problems in the power sector – the key growth market for gas – will need to be resolved, and financing must be found for LNG and cross-border pipeline projects. Some half of the projected growth in gas demand will be met by imports.
- Further reform of energy pricing is a vital precondition to the development of energy supply infrastructure in India. Foreign investors will have to provide an increasing part of the capital. The cumulative investment needed over the next three decades to meet the projected increase in generating capacity alone is estimated at around $270 billion.

CHAPTER 10: BRAZIL

HIGHLIGHTS

- The *Outlook* projects annual average growth of 3% in primary energy supply over the next three decades in Brazil. Oil and hydropower are expected to remain the key fuels in its energy mix. But gas will make major inroads in power generation, particularly towards the end of the projection period.
- Brazil has large deep-water oil and gas resources. Its ability to exploit them, however, is uncertain, because doing so will be very costly and will require heavy investment. The *Outlook* expects Brazil to become self-sufficient in oil by the second decade of the projection period.
- Over the long term, gas will be increasingly important for Brazilian power generation, partly because new hydro sites are located far from consuming centres. The share of gas in the power generation mix is negligible today, but the *Outlook* expects that, by 2030, it will rise to 35%.
- Gas import dependence will rise rapidly in the first decade of the *Outlook* period. But Brazil is expected to tap its vast gas resources, and import dependence will fall to some 5% by 2030.
- Investment in power projects has so far fallen short of expectations due to Brazil's unstable regulatory regime and unattractive power generation prices. This *Outlook* projects that investment of some $160 billion will be needed over the next three decades to build the necessary additional generating capacity.

CHAPTER 11: INDONESIA

HIGHLIGHTS

- As a major energy exporter and an increasingly important consumer, Indonesia will continue to play an important role in international energy markets. The country's primary energy demand is projected to grow rapidly in the next three decades, at an average 3.5% per year.
- Now an oil exporter, Indonesia will become a net oil importer in the second decade of the *Outlook* period. Production will continue to decline at existing fields, and domestic demand will rise rapidly, mainly for transport. Oil will still dominate Indonesia's fuel mix in 2030.
- Indonesia is the world's largest exporter of liquefied natural gas. Indonesian gas will increasingly supply growing markets in the Asia-Pacific region, including Japan and Korea. Domestic gas demand will also rise over the *Outlook* period, at an average 3.4% per year.
- Final electricity demand will grow rapidly, by over 5% a year, nearly doubling its share in final consumption by 2030. There could be an electricity shortage in the next few years. Investment in new power projects will be crucial to meeting projected demand. The *Outlook* estimates that $73 billion must be invested in power plants over the projection period.
- Uncertainties surrounding the energy projections for Indonesia are particularly acute. The economy is still reeling from the effects of the 1997 economic crisis. The recent global economic downturn, together with political instability at home, is clouding near-term prospects for sustained economic growth. Investor confidence will be crucial to Indonesia, both for its macroeconomic outlook and for the development of its energy supply projects.

CHAPTER 12: THE OECD ALTERNATIVE POLICY SCENARIO

HIGHLIGHTS

- Implementation of policies currently under consideration in OECD countries would reduce CO_2 emissions by some 2,150 Mt in 2030, or 16%, below the Reference Scenario in 2030. This is roughly equal to the total emissions of Germany, United Kingdom, France and Italy today. Because of the slow pace at which energy capital stock is replaced, CO_2 savings in earlier years are relatively small – only 3% by 2010 and 9% by 2020. Total OECD CO_2 emissions would eventually stabilise, but only towards the end of the *Outlook* period.
- Energy savings, which amount to 9% of the primary energy demand of the Reference Scenario in 2030, are smaller than CO_2 savings, because the latter reflect the benefits of both energy savings and fuel switching to less carbon-intensive fuels.
- The biggest reduction in CO_2 emissions will come from the power generation sector because of rapid growth of renewables and savings in electricity demand. This reflects the emphasis that OECD governments are currently giving to renewables and energy efficiency in their long-term plans for curbing CO_2 emissions and enhancing energy security.
- The reductions in energy demand lower the OECD's dependence on oil and gas imports. In 2030, OECD gas demand will be reduced below the Reference Scenario by 260 bcm, or 13%. The reduction in EU gas imports in 2030 is slightly less than today's imports from Norway and Russia combined. The savings in oil demand, stemming mainly from the transport sector, reach 4.6 mb/d, or 10%.
- Reductions in CO_2 emissions below the Reference Scenario will be largest in the European Union at 19% in 2030, followed by Japan, Australia and New Zealand at 15%, and the United States and Canada at 14%.
- Despite these reductions, the three OECD regions do not individually reach their targets under the Kyoto Protocol. However, if the United States is excluded, their targets could be

met through the savings achieved in this Alternative Policy Scenario and the emissions credits from other Annex-B countries.

- If governments wish to achieve larger or faster savings in energy and CO_2 emissions, they will need to take stronger measures to shape long-term energy and environmental outcomes.

CHAPTER 13: ENERGY AND POVERTY

HIGHLIGHTS

- Some 1.6 billion people – one-quarter of the world population – have no access to electricity. In the absence of vigorous new policies, 1.4 billion people will still lack electricity in 2030.
- Four out of five people without electricity live in rural areas of the developing world, mainly in South Asia and sub-Saharan Africa. But the pattern of electricity deprivation is set to change, because 95% of the increase in population in the next three decades will occur in urban areas.
- Some 2.4 billion people rely on traditional biomass – wood, agricultural residues and dung – for cooking and heating. That number will *increase* to 2.6 billion by 2030. In developing countries, biomass use will still represent over half of residential energy consumption at the end of the *Outlook* period.
- Lack of electricity and heavy reliance on traditional biomass are hallmarks of poverty in developing countries. Lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create.
- Investment will need to focus on various energy sources, including biomass, for thermal and mechanical applications to bring productive, income-generating activities to developing countries. Electrification and access to modern energy services do not *per se* guarantee poverty alleviation.
- Renewable energy technologies such as solar, wind and biomass may be cost-effective options for specific off-grid applications, while conventional fuels and established technologies are likely to be preferred for on-grid capacity expansion.

ORDER FORM

IEA BOOKS

Fax: +33 (0)1 40 57 65 59
E-mail: books@iea.org
www.iea.org/books

INTERNATIONAL ENERGY AGENCY

9, rue de la Fédération
F-75739 Paris Cedex

I would like to order the following publications

PUBLICATIONS	ISBN	QTY	PRICE		TOTAL
☐ **World Energy Outlook 2002**	**92-64-19835-0**		**$150**	**€165**	
☐ Energy Balances of Non-OECD Countries 2002	92-64-09786-2		$110	€120	
☐ Electricity Information 2002	92-64-19793-1		$130	€145	
☐ Coal in the Energy Supply of India	92-64-19799-0		$80	€88	
☐ Distributed Generation in OECD Electricity Markets	92-64-19802-4		$75	€82	
☐ Electricity in India	92-64-19724-9		$125	€137	
☐ Security of Supply in Electricity Markets	92-64-19805-9		$100	€110	
☐ Oil Information 2002	92-64-09792-9		$150	€165	
			TOTAL		

DELIVERY DETAILS

Name _____ Organisation _____

Address _____

Country _____ Postcode _____

Telephone _____ E-mail _____

PAYMENT DETAILS

☐ I enclose a cheque payable to IEA Publications for the sum of $ _____ or € _____

☐ Please debit my credit card (tick choice). ☐ Mastercard ☐ VISA ☐ American Express

Card no: _____ Signature:

Expiry date: _____

OECD PARIS CENTRE
Tel: (+33-01) 45 24 81 67
Fax: (+33-01) 49 10 42 76
E-mail: distribution@oecd.org

OECD BONN CENTRE
Tel: (+49-228) 959 12 15
Fax: (+49-228) 959 12 18
E-mail: bonn.contact@oecd.org

OECD MEXICO CENTRE
Tel: (+52-5) 280 12 09
Fax: (+52-5) 280 04 80
E-mail: mexico.contact@oecd.org

You can also send your order to your nearest OECD sales point or through the OECD online services: www.oecd.org/bookshop

OECD TOKYO CENTRE
Tel: (+81-3) 3586 2016
Fax: (+81-3) 3584 7929
E-mail: center@oecdtokyo.org

OECD WASHINGTON CENTER
Tel: (+1-202) 785-6323
Toll-free number for orders:
(+1-800) 456-6323
Fax: (+1-202) 785-0350
E-mail: washington.contact@oecd.org

IEA PUBLICATIONS - 9, rue de la Fédération - 75739 PARIS CEDEX 15
PRINTED IN FRANCE BY LOUIS-JEAN

Book cover by Bertrand Sadin