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World Energy Outlook

An Interactive Qualifying Project Report

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by

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Abstract

This project involved the study of the long-term forecasts of the world energy market provided by the U.S. Department of Energy, International Energy Agency, and some other private and governmental agencies. The team conducted a comparative analysis among these forecasts and a detailed investigation of the uncertainties that could shape the global energy market in the next two decades. This study focused on the assessment of the future of the world oil market and particularly the role of OPEC as a powerful oil producer.

Authorship

Both team members of the project contributed equally in the accomplishment of this project.

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1. Project Overview

1.1. Introduction

Everything is based on energy. Energy is the source and control of all things, all values, and all the actions of human beings and nature. This simple truth, long known to scientists and engineers, has generally been omitted from most education in this country. When energy sources are rich, economies, knowledge, and aspiration grow; when energy sources are all being used as fast as the earth receives them, activities, values, and aspiration settle into a steady pattern. So it has been throughout the history of humanity and nature. Therefore, it is essential to understand long-term energy possibilities if humanity is to build a more prosperous and equitable future. For this reason, we have considered the energy forecasting system to be interwoven with broader issues of human development.

The current global demand and supply for energy, coupled with the environmental consequences of carbon emissions is causing a mounting concern for the sustainability of our future energy supplies. While rapid economic in developing countries stimulates the world economy, it also increases pressures on energy supply and the environment.

The aim of this project is to identify and discuss the main key factors and uncertainties affecting the future of the world energy market. Our analysis will be based on long-term global and regional energy perspectives conducted by the International Energy Agency (IEA), the U.S. Department of Energy (DOE), in addition to some other private and governmental agencies.

First, the paper will give a short overview of the DOE and IEA scenarios, and then discuss the determinants of long-term energy forecasting. We'll also discuss the

demographics, geopolitics, infrastructure, technology investments, and environmental issues that can shape the future of the energy market. In addition, we will compare the projections prepared by these agencies and the degree to which they took into consideration the uncertainties that could affect the outlook of the energy market. Our analysis will be supported by a case study the role of OPEC in influencing the international energy market. We will conclude the project by discussing the significance of the key assumptions and uncertainties taken into consideration in projecting the future of the energy market. The argument will be supported by the study of OPEC's role in potentially shaping the future of energy.

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2. THE DOE INTERNATIONAL ENERGY OUTLOOK

The International Energy Outlook 1999 (IEO99) is an extension of the Energy Information Administration's (EIA) Annual Energy Outlook 1999 (AEO99), which was prepared using the National Energy Modeling System (NEMS). It presents an evaluation by the EIA of the outlook for international energy market through 2020. Projections in IEO99 were made for six primary country groupings. The report begins with a review of world trends in energy demand from 1970 to 1996. Its projections cover a 24-year period. They provide an objective, policy-neutral reference case that can be used to analyze international energy markets. In the reference case projections, assumptions are based on current U.S. and foreign government policies. In addition to the reference case, two patterns of economic growth, high and low, were used to generate alternative growth paths for the energy forecast. These two alternative growth paths consider different levels of future growth in regional Gross Domestic Product (GDP). The first part of the report describes the uncertainties involved in making international energy projections. It also discusses the status of environmental issues, including global carbon emissions associated with the outcome of the IEO99.

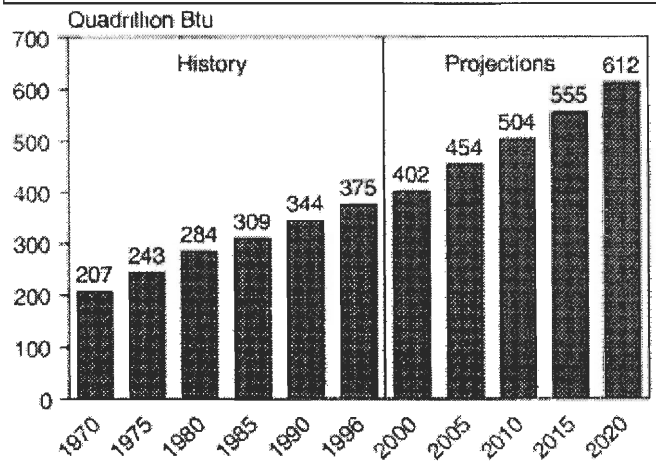
The next part of the report is setup by energy source. It contains a review of the present status of each fuel source on a worldwide basis as well as regional consumption projections for oil, natural gas, coal, nuclear power, and renewable energy sources (hydroelectricity, geothermal, wind, solar, and other renewable energy sources).

The third part looks at energy consumption in the end-use sectors, which includes electricity generation and transportation. It also describes environmental issues related to energy consumption.

2.1. World Energy Consumption

The IEO99 reference case projects that world energy consumption is an increase of 65 percent over the 24-year projection period. Consumption is expected to reach 612 quadrillion British thermal unit (Btu) by 2020 (Figure 1). The projections of world energy consumption is 4 percent lower for the IEO99 than the IEO98, which is an almost 30 quadrillion Btu drop in total energy consumption. This change of projections is attributed to the unexpected effects of the Asian crisis that began in the spring of 1997 and carried through the year of 1998 and deepened the economic recession in Japan. In Russia, the economy crashed as the Ruble devaluated and the Russian banking system collapsed. These problems along with the unexpected warmer winters in North America and Europe in 1998 resulted in worldwide energy surpluses which have, in turn, helped oil prices to slump to their lowest in 20-years. Thus, oil and gas investments sharply declined in most parts of the world at the end of 1998.

Figure 1.World Energy Consumption, 1970-2020



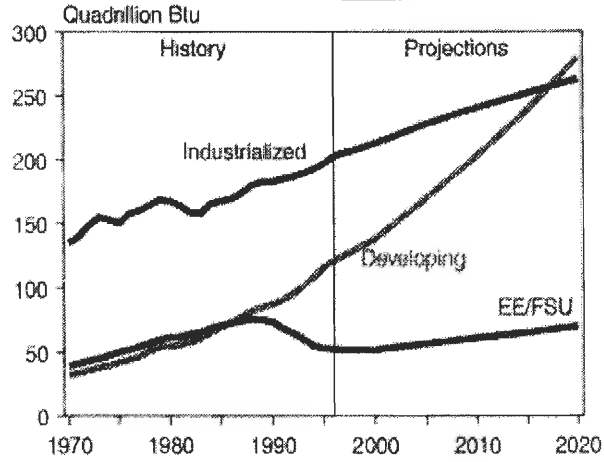
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/ EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

The pattern in energy demand is expected to reach a lower level of aggregate demand in the later years of the projection period than expected in the IEO98, as well as lower predicted oil prices for the next few years, followed by a recovery within the next few years of the projection period. Energy consumption in the developing countries (the

Middle East, Africa, developing Asia, and Central and South America) is expected to grow dramatically and double by 2020 with the highest growth rates in Central and South America and developing Asia. Although the energy consumption is 40 percent lower in the developing countries than that of the developed countries in 1996, it is expected to exceed the energy consumption in the developed countries by 6 percent (Some 16 quadrillion Btu) by the year 2020 (Figure 2).

The energy consumption in the former Soviet Union and Eastern Europe is expected to have a negative growth rate during the beginning of the projection period. However, a positive recovery is expected to begin by 2005, but even at the end of the projection period consumption remains below its 1990 levels.

Figure 2. World Energy Consumption by Region 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/ EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

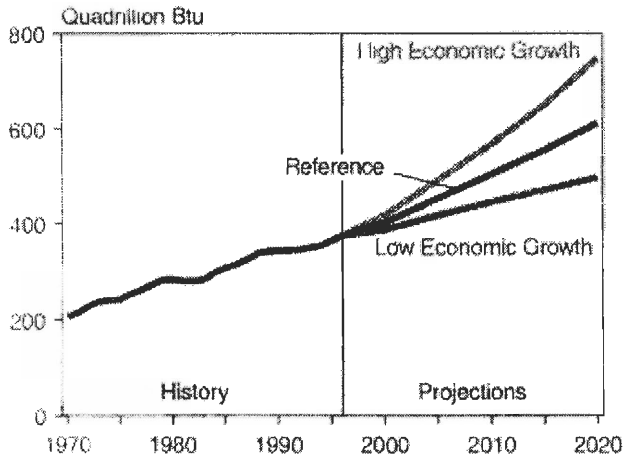
The DOE/ EIA recognizes that all projections made in the IEO99 are subject to important uncertainties that can dramatically change the future course of events affecting trends in the composition, cost, and level of energy use. Since economic growth and energy use are closely tied, alternative economic growth patterns were tested to determine the impact on the reference case projections.

The reference case projections depend on the continued effective application of economic policies designed to counter recession and foster structural reforms within national economies. On the other hand, political forces are changing in various countries,

which could lead, to economic stresses and social tensions. Therefore, alternative growth cases presented in the IEO99 provide a useful insight into the effects of unexpected changes and outcomes to assist in the analysis and projection of world energy growth (Figure 3).

An additional uncertainty includes the commitments being made by the developed countries under the Kyoto Protocol, which demands that these countries reduce their carbon emissions into the atmosphere. If this protocol is ratified and implemented, a shift in energy consumption and production would take place.

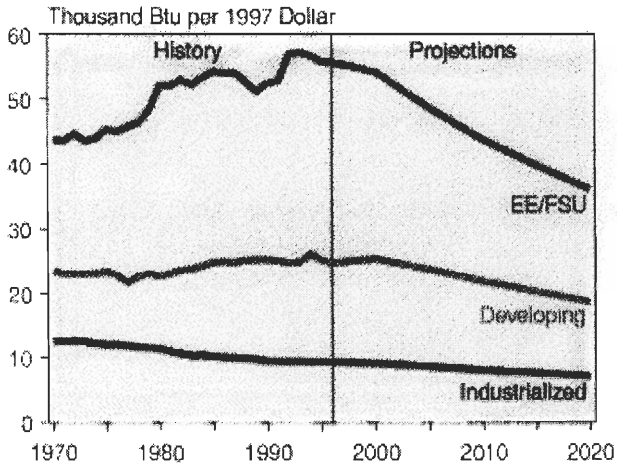
Figure 3. World Energy Consumption in Three Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998) **Projections:** EIA, World Energy Projection System (1999)

Another source of uncertainty for the long-term evolution of energy markets relates to trends in energy intensities. Energy intensity is defined as the manner in which energy requirements evolve relative to growing income levels. In the developed countries, energy requirements have grown slowly relative to increasing levels of economic activity. In the developing countries, energy and economic growth have tended to move in parallel (Figure 4). This is due to the economic development and rising living standards that lead to excess use of electricity and motorized means of transportation. This is expected to change; however, as economies continue to develop, the rate of energy use tends to fall relative to economic expansion.

Figure 4. World Energy Intensity by Region, 1970-2020



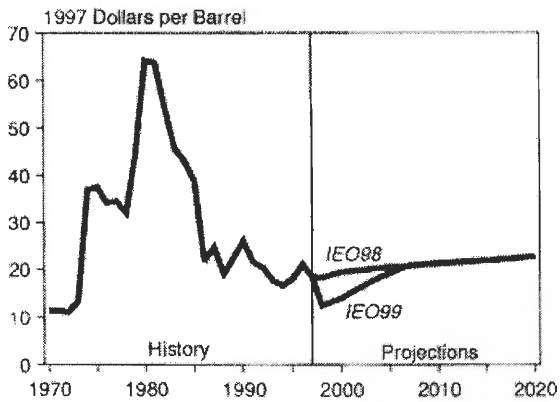
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database, and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Other key assumptions underlying the IEO99 reference case projection involve the continuing evolution of world oil markets. The reference case assumes a price recovery path that begins in 1999 to reach 20 dollars per barrel (constant 1997 U.S. dollars) by about 2007. It also expects a long-term recovery in demand growth and only a modest constriction in oil supply. Ironically, the reference case projection assumes no change in the influence of the Organization of Petroleum Exporting Countries (OPEC) on oil markets.

2.2. Oil Market

Figure 5. Comparison of 1998 and 1999 World Oil Price Projections

The IEO99 reference case projects a slow recovery in oil prices over the next several years from its record low prices in 1998. This slow recovery is a result of a surplus oil supply being used to meet a slower demand growth than projected in IEO98 (Figure 5). World oil prices are expected to reach $23 per barrel (constant 1997 U.S. dollars) at the end of the projection period. For the mean time, however, the IEO99 price trajectory is substantially altered by the plummeting oil prices in 1998. The



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). ***IEO98:*** EIA, *International Energy Outlook 1998*, DOE/EIA-0484(98) (Washington, DC, April 1998). ***IEO99:*** EIA, World Energy Projection System (1999).

path of recovery along which the oil prices and oil demand will rebound is the source of much uncertainty.

Oil is projected to remain the dominant energy source even as its share of world energy consumption slips somewhat over the next two decades, falling from 40 percent to 38 percent as countries switch to natural gas and other types of fuel for the purpose of power generation. However, the loss of oil use in the power sector will be replaced by an increase in oil demand for transportation. Oil consumption is projected to increase in the industrialized countries in the transportation sector, where competition from other fuels is limited. In the developing countries, oil use for transportation increases more rapidly than in the industrialized countries. Increasing industrial activities will be met in part by using oil, especially in Asia, where natural gas is less available than it is in North America and Europe.

2.3. Natural Gas Market

Natural gas is expected to be the fastest growing primary energy source from 1996 to 2020 at an average growth rate of 3.03 percent per year. It is the fuel of choice for new electric power generation because combined-cycle gas turbine plants tend to be less expensive to build and operate than other means of power generation.

Natural gas use is expected to exceed coal consumption within the next decade. Moreover, among fossil fuels, natural gas is the most likely to be in greater demand because of favorable supply and demand balance and increasingly stringent environmental regulation. Natural gas has environmental benefits because of its clean burning characteristics and low carbon contents as compared with other fossil fuels.

Local air pollution can be lessened by shifting from coal to natural-gas-fired generation. On a btu basis, carbon emissions from natural gas combustion are less than half those for coal. _

2.4. The Coal Market

World coal use is projected to increase by 2.4 billion short tons, from 5.2 to 7.6 billion short tons, between 1996 and 2020. Strongest growth in demand is projected for the developing world where coal use will double within the next 20 years. Its use will grow at a rate of 3.0 percent annually to meet the demand in power generation in these countries. In the IEO99, China and India are expected to account for more than 90 percent of the growth in worldwide coal consumption between 1996 and 2020. This growth is attributed to the increase in the demand for power. In the industrialized countries, coal use is expected to be the same through 2020, while in the Eastern Europe and former Soviet Union it is expected to decline by almost 30 percent.

2.5. Nuclear Power

Nuclear power supplied 10 countries with at least 40 percent of their total electricity demand, and had a 17 percent share of world electricity generation. Within the next two decades, however, nuclear power is expected to decline according to the IEO99 reference case. Only developing countries and Japan have a net addition to their nuclear power supply by the year 2020.

In other regions, countries that are currently operating nuclear power plants would look for more economical and efficient options to increase their generation capacity and

replace the retired reactors. Market competition for natural gas, problems associated with the disposal of radioactive wastes, and public concern with the safety of nuclear power plants are affecting the future of nuclear power programs in many nations. On the other hand, ratification of the Kyoto's protocol could change the future of the nuclear power. Nuclear power under high capacity scenario could reduce projected world carbon emissions by 6 percent by 2020, or an estimated 206 million metric tons.

2.6. Renewable Energy Sources

The high availability and low prices of fossil fuel continue to diminish the potential for rapid development of renewable energy sources worldwide. In the IEO99 reference case, hydroelectricity and renewable energy sources maintain an 8-percent share of total energy consumption throughout the projection period.

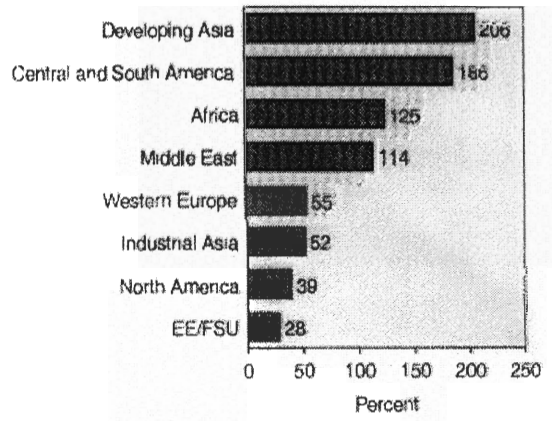
Hydroelectricity would occupy almost a half of the renewable energy sources share during this period due to the boost in hydroelectric programs in many of the developing countries especially India and China. It is possible that ratification of the Kyoto's Protocol could change the outlook for renewable energy sources.

2.7. Energy by Sectors

2.7.1. Electricity

World net electricity consumption is expected to increase from 12 trillion Kilowatthours in 1996 to 22 trillion kilowatthours in 2020 (Figure 6). Electricity demand in the developing countries is projected to increase an average rate of 4.4-percent per year, and the strongest long-term growth is projected for the developing countries of Asia, as well as Central and South America. Population growth, industrialization, and growing household electrification will increase electricity demand in these regions. In the industrialized countries, electricity demand is expected to increase at an average rate of 1.6-percent per year, due to the increase use of electricity-using equipment.

Figure 6. Projected Change in Net Electricity Consumption by Region, 1996-2020



Sources: **1996:** Energy Information Administration (EIA), *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **2020:** EIA, World Energy Projection System (1999).

2.7.2. Transportation

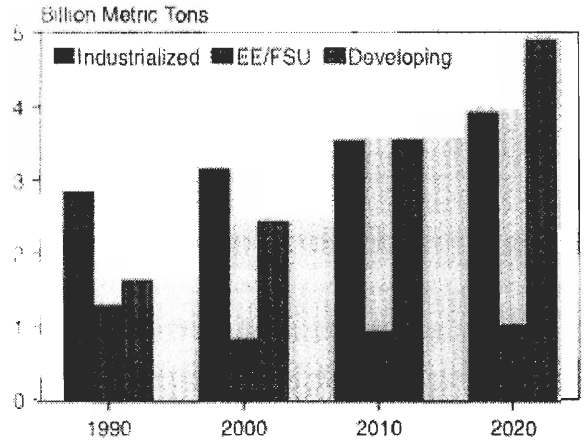
Transportation is considered an excellent indicator of a nation's economic development. Over the next two decades, fast-paced growth in the transportation infrastructure is expected to occur in the developing countries. Central and South America and developing Asia are expected to account for 52 percent of the increase in the world's motor vehicle population between 1996 and 2020.

According to the IEO99 reference case projection, energy use for transportation among the developing countries is projected to grow at an average annual rate of 4.0 percent as opposed to 1.4 percent among the industrialized countries. The high growth in transportation is attributed to higher income levels, increased purchases of personal transportation, and increased travel for business and vacation.

2.8. Environmental Issues

A major issue that would affect the development of energy markets is the possible impact of the Kyoto Climate Change Protocol. It would require reductions or limits to the growth of carbon emissions within the Annex I countries* between 2008 and 2012, resulting in a combined 4-percent reduction in emissions relative to 1990 levels. As of March 15, 1999, 83 countries had signed the Kyoto Protocol; however, none of the Annex I countries had ratified it by the time the IEO99 was prepared for publication.

Figure 7. World Carbon Emissions by Region, 1990-2020



Sources. **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998) **Projections:** EIA World Energy Projection System (1999)

If energy growth was similar to the IEO99 reference case projection, annual carbon emissions will reach 8.0 billion metric tons in 2010 and 9.8 billion metric tons in 2020 (Figure 7). Hence, world carbon emissions would exceed 1990 levels by almost 39 percent in 210 and by 70 percent in 2020. Clearly, if the Kyoto Protocol were ratified and implemented, it may well

influence carbon emissions levels in the future. However, only 2 of the 67 countries that had signed the Kyoto Protocol as of December 1998 have actually ratified it. IEO99 reference case projections have not been adjusted to account for changes that occur under the protocol.

In the industrialized world, carbon emissions are projected to increase from 2.9 to 3.9 billion metric tons between 1990 and 2020, an increase of just over 1.0 billion metric tons. Carbon emissions grow most quickly in the developing countries. By 2010, their emissions are expected to surpass the levels of the industrialized countries, whereas in 1990 developed countries' emissions were nearly two times those of the countries of the developing world.

In the Eastern Europe and former Soviet Union region, carbon emissions remain below their 1990 levels throughout the projection period due to the economic crisis and political conflicts that took place in the 1990s. By 2010, emissions are expected to be 27 percent lower than 1990 level and by 21 percent by 2020. The slight increase in emissions between the two decades is attributed to the expected recovery of the region's economy.

2.9. Alternative Growth Cases

In order to consider uncertainties related to economic growth patterns, IEO99 includes a low economic growth case and a high economic growth case in addition to the reference case. The reference case projections were based on a set of regional assumptions about economic growth paths and energy elasticity (the relationship between changes in energy consumption and changes in GDP). However, the two alternative

growth patterns were established to quantify the range of uncertainty associated with the reference case (Figure 3).

The high and low economic growth paths involve the same pattern of change in energy intensity relative to GDP as in the reference case. For each of the six country groupings, increments of positive and negative percentage points were added to the reference case growth rates to generate high and low growth rates respectively (Table 1). Increments of percentage points were based on analysis of each region's potential for growth.

Table 1. High economic growth case, low economic growth case, and the reference case projections.

Economic Growth by Region
(Average Annual Percentage Growth)

Region	1995-2020 DOE/IEO99		
	Low Growth	Reference	High Growth
Industrialized Countries	1.3	2.3	3.2
North America	1.4	2.4	3.3
Western Europe	1.4	2.4	3.4
Pacific	0.9	1.9	2.9
EE/FSU	1.4	2.9	5.7
Former Soviet Union	0.5	2	4.8
Eastern Europe	2.7	4.1	7
Developing Countries	3.1	4.8	6.3
Asia	3.3	5.3	6.8
China	3.8	6.7	8.1
Other Asia*	3.1	4.6	6
Middle East	2.6	4.1	5.5
Africa	2.1	3.6	5
Central and South America	2.9	4.3	5.7
Toatal World	1.7	2.9	4

* Other Asia includes India and South Korea.
Sources: IEO 99: Energy Information Administration (EIA), World Energy Projections System (1

2.10. Trends in Energy Intensity

The way energy demand evolves relative to GDP over time, affects long-term energy demand developments. IEO 99 states that the link between economic growth and energy demand is greatly influenced by the standard of living of individuals and the stage of economic development (Figure 4).

Advanced economies with high living standards could lead to an increase in energy use, which correlates with employment and population growth. In the industrialized countries, economic growth leads to a high consumption of modern appliances and motorized transportation equipment. However, the new technologies are often more efficient than the equipment they replace, resulting in a weaker link between income and energy demand. In the developing countries, standards of living rise at a higher rate relative to those in more advanced economies. As a result, many energy-using devices are being widely used for the first time, causing energy use to track rising income levels more closely. In conclusion, energy consumption in the projection period depends on the growth patterns of energy intensity.

3. The International Energy Agency, World Energy Outlook 1998 "Business As Usual" Scenario

The IEA business as usual scenario, presented by Jean-Marie Bourdaire in the World Energy Outlook 1998, is based on fairly standard economic and demographic assumptions. World economic growth is projected at 3.1 per cent per year, close to its average for the past twenty-five years, with higher growth rate in developing countries and the transition economies, and lower rates in the OECD area. World population is expected to increase substantially, even though at a gradually slower pace, reaching 8 billion in 2020. Total energy use rises by 2 per cent per year and energy intensity decreases by 1.1 per cent per year. There is a risk, however, that energy efficiency improves more slowly than expected in China and the transition economies. CO2 would rise in parallel with the primary demand due to the leveling off nuclear power generation and to rapid growth in coal use in China and other Asian countries.

One striking feature of the over all picture is the existence of an autonomous energy efficiency increase, resulting from the introduction of improved technologies.

3.1. Relative Stability in the Energy Demand Patterns

Three uses are considered in the energy demand: electricity, mobility, and stationary uses (mostly heating). In the OECD countries, electricity and mobility have been remarkably stable in the past, growing broadly in line with GDP in spite of the oil price shocks of 1973 and 1979. Stationary uses, on the other hand, have been effected by the oil shocks through sharp energy efficiency increases, rising demand for low-energy service activities, and the relocation of some industrial activities to developing countries.

These trends are largely expected to continue in the coming decades, but some important variations. In developing countries, energy use is likely rise remarkably, due to higher living standards of living, population growth, rapid urbanization and gradual substitution of noncommercial fuels by commercial fuels. In contrast, the transition economies for example Central and Eastern Europe, some North African countries, and the newly independent states of the former Soviet Union, are entering a period of reconstruction of economic, social, and institutional policy in order to harmonize and integrate with the international economy. Therefore the projection of the impact of these countries on the world energy market will be subjected to many uncertainties. Finally, OECD countries might experience some saturation in stationary uses (heating in particular), but the extent and timing are difficult to predict. The non-OECD countries will play much more important role than they do at present, both in terms of demand and supply, and in terms of CO_2 emissions.

3.2. Fossil Fuels Remain Predominant in the Energy Supply

Up to around 2020, energy use will continue to be largely dominated by fossil fuels. Oil consumption will be driven by transport needs, and the fact that oil will remain the "swing" energy, that fills the gap when the other energies are not available to a sufficient extent. Use of gas will grow rapidly as the preferred fuel for heating and power generation. Coal use will grow, even though more slowly in the generation sector, where gas is not available or more costly than coal. Nuclear fission, hydropower, and biomass as major non fossil sources, will probably see

their part in over all supply decline. Biomass, still predominant in some developing countries, could be reduced by shifting from noncommercial to commercial fuels as real

income increase in these countries. Oil and gas prices look set to remain fairly stable up to 2010, but then increase by 50 per cent at some date between 2010 and 2020, as marginal supply shift from conventional to non-conventional oil. However, with supply of conventional oil increasingly concentrated in the Middle East, and with reserves of natural gas in Russia, Iran and part of Central Asia becoming more important, the probability of short-term price disruption could well rise.

Electricity: is dominated by the use of fossil fuels, at least if the least-cost criterion is applied in forecasting choices of new generating plants.

Nuclear, hydro and other renewable sources: they are not universally competitive under currently expected price structures and /or suffer from variety of difficulties in gaining public acceptance.

Coal: the coal use is expected to remain heavy in North America as well as in China and other developing countries.

Gas: gas use should develop rapidly, in particular, in producing countries, partly in combined-cycle generating plants.

Oil: oil finally, will continue to be used as stand by fuel in times of peak demand, gas supply disruption or gas price increases.

4. The World Energy Outlook for the Next Fifty Years

4.1. The International Energy Agency (IEA)

The period 2010 to 2020 is considered to be the transition period for the energy systems. By 2050, the world population will have increased by more than 2 billion people. Moreover, the OECD countries will be an increasingly smaller energy player in the world in terms of demand, production and trade, but nonetheless remain important as a suppler of technology. The security of energy supply will be a concern shared by most countries.

The major changes in the energy mix picture could accrue in the oil and gas supply, and climate change policies may have a large impact.

New technologies are set to emerge and new infrastructure will be built to sustain production and facilitate trade. In many countries, public energy industries are likely be privatized leading to more competition in energy networks, the shifting from the raw products (biomass) to more convenient energy services will be the major drivers of these changes.

This transition of the world's energy sector could well accelerate over the period 2020-2050. The kind of energy could that will be shaped by multitude of opportunities and constraints. For example, many end-use industrial processes, heating systems, parts of the building stock and infrastructures will begin to be replaced by new technologies, and many existing power plants will be at the end of their lifetime. By 2050 all energy

technologies and devices will have been replaced at least once, offering possibilities to more energy efficient path. However, there is a concern that the improvement rate of the energy intensity is on decline, because the technologies require continual investment of efforts and money for steady improvement. Moreover, the increasing concern regarding the concentration of greenhouse in the atmosphere over the long term will make it essential to invest in technologies and policies that allow the compliance with stricter environmental target.

4.2. The International Institute for Applied Systems Analysis (IIASA)

The IIASA has developed four scenarios concerning the world energy outlook for the next fifty 50 years. The four scenarios are, incorporating technologies, resources, infrastructures and the financial institutions.

First two scenarios, free trade, favorable geopolitics, and economic growth, which attains an average of 2.7 per cent per year between 1990 and 2050. In turn, high growth enables faster turnover of stocks and facilitates structural change in the energy sector. Efficiency improvement is moderate (1 per cent per year). The second scenario sees a more intensive use of oil and gas resources, both conventional and unconventional, and a late transition to nuclear and new renewables. Carbon emissions reach 12GT (gigatons) by 2050. Alone the solar energy transmitted to the earth every year is around 130,000 Gtoe (gigaton oil equivalent), compared to a current total energy consumption of 9 Gtoe. The constraints are not on the potential itself, but on how it will be exploited.

The second feature of the scenarios is that, even though the fossil period will probably have passed, oil and gas still provide huge quantities of energy through 2050

and increase more or less rapidly afterwards. Renewables emerge in all scenarios as the major source of the energy in the longer term, albeit at substantially different levels. The future of nuclear fission by contrast will depend upon improved technology and commercial viability as well as public acceptability taking into consideration both the safety and the security dimensions.

4.3. The Uncertainties Contained in the IEA and IIASA Projections

The OECD' s Advisory Unit to the Secretary-General claimed that the IEA and IIASA projections contain a number of significant uncertainties. There are related to two major issues: energy security and geopolitical outlook on the one hand, and environmental impacts and policies on the other. Important difficulties might surround key aspects of energy demand, for example, the saturation level in the OECD countries, the future trends of mobility in both OECD and non-OECD countries. Finally, there are some important questions marks concerning production and energy system generally.

Other uncertainties surround key assumptions of the scenarios, the first question relates the productivity growth and ultimately, economic growth in the non-OECD countries over the coming decades. At the very least it seems safe to assume that, even though developing countries will not bypass steel, machinery, chemical and other industries, the changing nature of production and user technologies (especially the pervasiveness of microelectronics) will ensure they don't repeat exactly the industrialization pattern of the OECD countries. there are, moreover, regional models which suggest that "leap-frogging" in the catch up process between some developing and developed countries could prove faster than foreseen, with the former shifting rapidly to

light industry and service activities. In either case, energy intensity in those countries could decline faster than expected. Moreover, as regards the transition economies, there are significant doubts surrounding the extent, length, and consequences of industry restructuring. The second uncertainty concerns the population growth. Population development can be estimated for twenty-year period with some degree of confidence. The population growth could peak before 2050 to reach 8 or 8.5 billion. Nevertheless, the potential cumulative margin of error over a period of fifty years is more worrisome. The third uncertainty concerns oil reserves. Some experts argue that given the existence of diminishing returns in oil prospecting, and the strong possibility that estimated ultimately recoverable oil reserves are lower than generally believed, production could start to dwindle sooner than expected according to some estimates, as early as 2007. in the following sections, the oil reserves will be discussed with more depth and analysis.

5. Forecast Comparisons

One way to illustrate the uncertainty associated with energy forecasts is to compare them with each other. Both, the International Energy Outlook 1999 provided by the EIA/ DOE and the World Energy Outlook provided by the IEA provide projections to the year 2020. The total world energy consumption forecasts are almost identical (Table 2). IEA projects a growth of 2.0 percent per year between 1995 and 2020, and IEO99 projects 2.1 percent annual growth.

Almost all the projected growth rates that extend through 2020 for the industrialized region fall within the range defined by the IEO99 low and high economic growth cases. One notable exception is the IEA projection for North America. IEA expects energy use in North America to increase by only 0.7 percent per year between 1995 and 2020, whereas the IEO reference case projects growth of 1.3 percent per year (Table 2). The IEA suggests that the differences between its projections for North America and the IEO99 projections may be attributed, in part, to its expectations of higher oil and natural gas prices.

In the IEO99 reference case and IEA 'business as usual' case, energy demand in developing Asia (All Asian countries except those considered as Other Asia, China, and Japan) is expected to increase by 3.7 percent per year between 1995 and 2020 (Table 2). Energy demand in "Other Asia" including Thailand, Indonesia, Malaysia, South Korea, and India hardest hit by the economic troubles that began in 1997 and continues throughout 1998, is expected to be 3.3 percent per year. It is clear that there is still much debate among analysts about the time frame needed for these countries to regain momentum for economic expansion and increased demand for energy.

Within Asia, there is more variation in expectations for "other Asia" than for China. IEO99 tend to be more conservative than WEO98. Between 1995 and 2020, IEO99 projects energy demand growth in other Asia of 3.3 percent per year. IEA projects 4.0 percent annual growth in other Asian energy use (Table 2).

Of the remaining developing regions, the greatest variation in expected growth is seen for Central and South America. IEO99 is more optimistic about growth in energy use in the region than the IEA, projecting growth of 4.3 percent per year over the 1995-2020 period, compared with 2.9 percent per year of the IEA (Table 2).

A key reason for the differences between both forecasts is that they are based on different expectations about future economic growth rates (Table 3). Thus, both forecasts have different expectations for economic growth rates for the industrialized regions. The IEA economic growth rates for North America, Western Europe, and the Pacific are lower than the corresponding IEO99 growth rate projections.

Projected GDP growth rates over the 1995-2020 period vary somewhat for the EE/FSU (Eastern Europe/Former Soviet Union) region, as might be expected given the economic straits in which the FSU, and specifically Russia, finds itself. While IEO99 assumes annual GDP growth of 2.9 percent for the region, IEA projects a more optimistic 3.3 percent per year (Table 3).

Projections vary not only with respect to the levels of energy demand and economic growth but also with respect to the composition of energy input use. IEO99 expects continued strong growth in world natural gas consumption, growing by 3.3 percent annually between 1995 and 2020. This growth rate is more optimistic than the 2.6 percent forecast by the IEA (Table 4).

Given the relatively high growth rate of expected gas use, IEO99 tends to have lower growth rates than the IEA for the remaining fossil fuels. In IEO99, oil use grows by 1.8 percent per year worldwide between 1995 and 2020, whereas the average annual growth rate is 1.9 percent from the IEA (Table 4). Coal use in IEO99 grows by 1.7 percent per year, but the IEA forecast projects an increase of 2.1 percent per year (Table 4).

Lastly, IEO99 projections of growth in the use of non-fossil fuels (i.e., nuclear power and hydroelectricity and other renewables) are lower than the IEA forecast by 0.4 (Table 4).

Table 2. Comparison of Energy Consumption Growth Rates by Region

Region	1995-2020 DOE/IEO 99				
	Low Growth	Reference	High Growth	IEO 98	IEA
Industrial Countries	**0.8**	**1.2**	1.6	1.2	1.0
North America	0.9	**1.3**	1.6	1.2	0.7
Western Europe	0.7	**1.1**	1.5	1.2	1.3
Pacific	0.5	**1.0**	1.6	1.3	1.0
EE/FSU	**0.5**	**1.1**	**2.4**	**1.7**	**1.7**
Former Soviet Union	0.2	0.9	2.2	1.6	---
Eastern Europe	1.1	1.7	2.8	1.8	---
Developing Countries	**2.2**	**3.6**	**4.7**	**3.8**	**3.4**
Asia	2.2	3.7	4.7	4.2	3.7
China	2.2	4.1	5.0	4.5	3.5
Other Asia*	2.2	3.3	4.3	3.8	4.0
Middle East	1.9	3.0	4.2	2.5	2.6
Africa	1.3	2.3	3.2	2.5	2.6
Central and South America	2.7	4.3	5.8	3.8	2.9
Total World	**1.2**	**2.1**	**2.9**	**2.3**	**2.0**

* Other Asia includes India, South Korea, Malaysia, Indonesia, and Thailand.
Source: ***IEO 99***: Energy Information Administration (EIA), World Energy Projections System (1999). **IEO**: *International Energy Outlook 1998*, DOE/EIA-0484 (98) (Washington, DC, April 1998), Table A1, p. 133. **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, pp. 412-463

Table 3. Comparison of Economic Growth by Region (Average Annual Percentage Growth)

Region	1995-2020 DOE/IEO 99				
	Low Growth	Reference	High Growth	IEO 98	IEA
Industrial Countries	**1.3**	**2.3**	**3.2**	**2.3**	2.1
North America	1.4	2.4	3.3	2.1	2.0
Western Europe	1.4	2.4	3.4	2.4	1.8
Pacific	0.9	1.9	2.9	2.3	---
EE/FSU	**1.4**	**2.9**	**5.7**	**3.7**	**3.3**
Former Soviet Union	0.5	2.0	4.8	3.6	---
Eastern Europe	2.7	4.1	7.0	4.4	---
Developing Countries	**3.1**	**4.8**	**6.3**	**5.2**	---
Asia	3.3	5.3	6.8	6.2	---
China	3.8	6.7	8.1	7.9	5.5
Other Asia*	3.1	4.6	6.0	5.2	4.2-4.5
Middle East	2.6	4.1	5.5	3.8	2.7
Africa	2.1	3.6	5.0	4.1	2.5
Central and South America	2.9	4.3	5.7	4.3	3.3
Total World	**1.7**	**2.9**	**4.0**	**3.1**	**3.1**

* Other Asia includes India, South Korea, Malaysia, Indonesia, and Thailand.
Source: ***IEO 99***: Energy Information Administration (EIA), World Energy Projections System (1999). ***IEO 98***: *International Energy Outlook 1998*, DOE/EIA-0484 (98) (Washington, DC, April 1998), Table A1, p. 133. ***IEA***: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, pp. 30.

Table 4. Comparison of World Energy Consumption Growth Rates by Fuel (Average Annual Percentage)

Region	1995-2020 DOE/IEO 99				
	Low Growth	Reference	High Growth	IEO 98	IEA
Oil	1.0	1.8	2.6	2.1	1.9
Natural Gas	2.5	3.3	4.2	3.3	2.6
Coal	0.6	1.7	2.5	2.2	2.1
Nuclear	-0.8	-0.3	0.3	-0.4	0.0
Renewable	1.2	2.0	2.8	2.1	2.5
Total	**1.2**	**2.1**	**2.9**	**2.3**	**2.0**

Source: ***IEO 99***: Energy Information Administration (EIA), World Energy Projections System (1999). **IEA**: *International Energy Outlook 1998*, DOE/EIA-0484 (98) (Washington, DC, April 1998), Table A1, p. 133. **IEA**: International Energy Agency, *World Energy Outlook 1998* (Paris, France, November 1998), Business As Usual Case, pp. 412-463

6. PETROLEUM MARKET

6.1. Introduction

Petroleum is a complex mixture of liquid hydrocarbon- chemical compounds containing hydrogen and carbon- occurring naturally within the earth. Early use of petroleum dates back many years. Man first became aware of its existent when its was discovered oozing to the surface from natural "seeps".

Because petroleum in its raw material state has limited uses, further processing of crude oil, via petroleum refining is needed to unlock the full potential of these resources. In the mid-1800's, the earlier refineries used a distillation processes to produce kerosene. Today's refineries employ many processes from simple distillation to a complex "cracking" and "reforming" operations to convert crude oil into a wide array of desired products. With approximately 20 percent of the world's crude oil distillation capacity and about 30 percent of the more complex cracking and reforming capacity, the United States leads the world in the production of petroleum products.

Although petroleum provides many useful products, the most notable are motor gasoline and heating fuels. Petroleum's many uses in the transportation sector include fuel for automobiles, trucks, agricultural, and industrial machinery, trains, ships, and aircraft. Petroleum is used to heat homes, offices, and factories. Petroleum is also the source of synthetic fabric for cloths as well as detergents and dry leaning solvent to clean them. Moreover, petroleum provides a chemical base for cosmetics and pharmaceutical products as well as for many plastic products from toys to building materials.

6.2. Oil Market in Recent Years

Oil has the largest share of any fuel in world primary energy supply. In 1995, the oil's share of the worldwide energy market was accounted for 38.3 percent (*OWEM, 1998).* Transport fuels Are the fastest growing element and currently account for over half of oil demand. The reminder is used mainly for heating in building, industrial processes, power generation. Oil products can be easily transported and stored. Other fuels such as coal, gas, nuclear power, hydro and other renewables are less flexible. This chapter presents a study of the oil supply and demand, including an analysis of the DOE and IEA oil projections for the next two decades.

The world oil price in 1998 was the lowest since 1973 (1998 dollars). The declining prices were influenced by an unexpected slowdown in the growth of the energy demand worldwide and by an increase in oil supply. The decrease in the oil consumption in 1998 occurred because the recession in Southeast Asia proved to be more severe than expected. Significant reductions in Gross Domestic Product (GDP) were experienced in Korea, Thailand, and Malaysia. Political depression struck Indonesia. Japan, the region's largest economy, moved from slow economy growth or no economy growth to decline. Even though, the Chinese economy continued to grow, it was affected by reduction in trade with the neighboring countries.

By the mid 1998, the Organization of Petroleum Exporting Countries (OPEC) launched many agreements to restrict production within OPEC, and Non-OPEC producers. In both March and June, OPEC (excluding Iraq) and the Non-OPEC (Mexico and Norway) announced plans to cut the oil production by 2.1 and 3.1 million barrels per day respectively (*10^{th} Montreux Energy Roundtable, 19 April 1999*). In the remaining

months of 1998, however, announced and realized production cuts were not clearly coordinated, and production management efforts had at best only modest success. Oil-producing countries faced severe fiscal deficits, causing national oil companies to cut capital spending.

How should this development be extrapolated to construct the long- term oil outlook? We would anticipate low oil prices to continue if we expected that the recovery in Asia would be slow in the coming decades. The likelihood of this outlook is increased if the high technology is applied to oil recovery, or because resource rich countries including OPEC producers open their countries to high level of exploration and development activity.

6.3. Growth in Oil Demand

According to the DOE and IEA oil recent projections, the world demand is projected to increase by about 1.9 percent per year during the next two decades. Oil demand in the industrialized countries is projected to increase about one percent per year over the next twenty years. In the developing countries, demand is expected to increase strongly throughout the projection period at an average of 2.9 percent per year. The developing countries increase in demand for oil is likely to be dominated by demand growth in the Asian countries (*DOE/IEO 1999)*. In the World Energy Outlook (*IEA 98*), the demand for oil in Asia is projected to grow at an average rate of around 4 percent per year during the projection period 1995- 2020 (table 5).

Table 5. World Oil Demand – Oil Market Report Basis (Mbd)

Region / Countries	1995	2010	2020	1995-2020 (AAPC)
OECD	**40.6**	**48.1**	**50.7**	**0.9**
North America	19.8	23.4	24.1	0.8
Europe	14.1	17.0	18.7	1.1
Pacific	6.7	7.7	7.9	0.7
Non-OECD	**29.5**	**59.9**	**59.9**	**2.9**
Transition Economies	6.0	8.5	8.5	1.4
Africa	2.2	4.0	4.0	2.5
China	3.3	10.1	10.1	4.6
East Asia	7.9	19.5	19.5	3.7
Latin America	6.0	11.0	11.0	2.5
Middle East	4.1	6.3	6.3	1.7
World	**70.1**	**94.2**	**111.0**	**1.9**

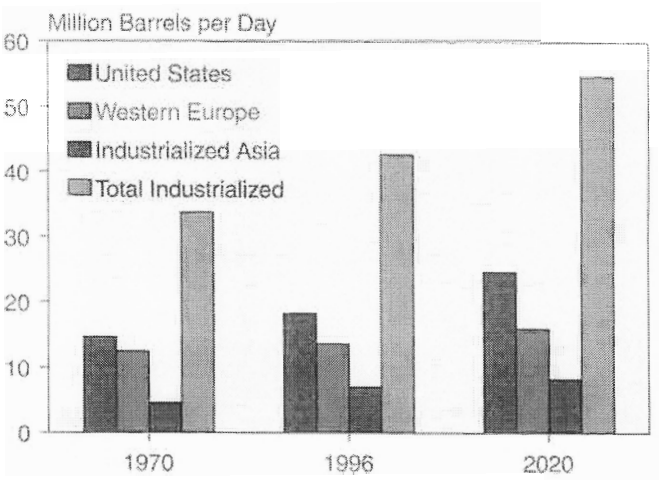
AAPC: Average Annual Percent Change
Source: IEA, *World Energy Outlook, 1998*

6.3.1. Industrialized countries

Many industrialized economies have reduced their reliance on oil in those applications where alternatives were available such as electric utility and industrial boilers and home heating.

More than half of the growth in oil consumption in industrialized countries is expected to occur in the United States (figure 8), where per capita car ownership and travel continues to rise. Western Europe is projected to amount for bout 20 percent of the growth in oil consumption; industrialized Asia (Japan, Australia, New Zealand) is expected to contribute about 10 percent of the growth in oil demand.

Figure 8. Oil Demand in Industrial Countries, 1970, 1996, and 2020

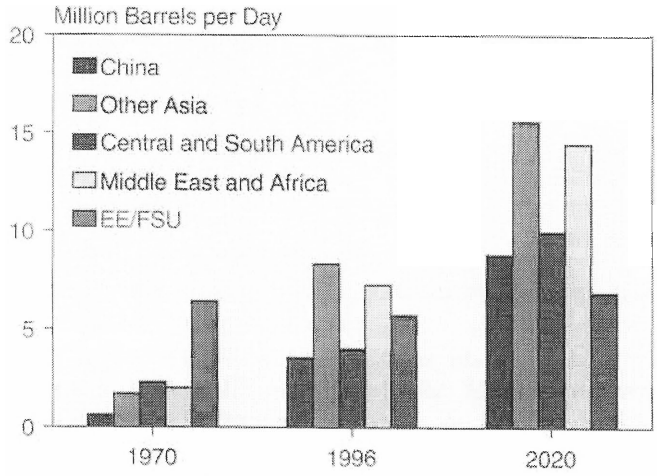


Sources: **1970 and 1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

6.3.2. Developing countries

The developing world, which accounted for less than one-third of the world's oil consumption in 1996, is expected to account for 44 percent of the oil market consumption by 2020. Almost 50 percent of the growth in oil consumption in developing countries is anticipated to occur in developing Asia (figure 9). Even though in the developing countries expectations have been adjusted downward in IEA 99 to reflect the economic crisis, the reference case projection continues strong potential for sustained economic growth (*DOE, 1999*).

Figure 9. Oil Demand in Non-industrialized Regions, 1970, 1996, and 2020



Sources: **1970 and 1996:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

6.3.3. Transport Sector

In all regions of the world, the largest increase in oil demand is expected to result from oil's use as transportation fuel. By 2020, transportation is expected to account for 52 percent of world oil consumption, up from 44 percent share in 1996 *(DOE, 1999)*. The developing countries transport sector's demand is projected to grow on average by 3.6 percent per year throughout the projection period 1995-2020 (table 6). In the industrialized countries, growth is somewhat lower, an average of 1.5 percent per year (*IEA, 1998*). The industrialized countries are still expected to consume more oil in the transport sector than the developed countries in 2020, this dominance is reflected by higher average vehicle ownership and per capita income levels.

Table 6. Transport Section Oil Demand (Mtoe) (*IEA 98)*

Region / Countries	1995	2010	2020	1995-2020 (AAPC)
OECD	**992.8**	**1317.5**	**1440.4.**	**1.5**
North America	571.5	708.7	739.9	1.0
Europe	307.2	461.3	545.4	2.3
Pacific	114.1	147.5	155.2	1.2
Non-OECD	**483.2**	**843.2**	**1178.5**	**3.6**
Transition Economies	63.7	98.5	131.2	2.9
Africa	39.4	55.2	67.1	2.1
China	52.2	122.8	182.4	5.1
East Asia	94.8	205.1	312.6	4.9
Latin America	130.4	202.3	260.8	4.5
Middle East	56.4	67.3	83.9	1.6
World	**1475.9**	**2160.7**	**2619.0**	**2.3**

AAPC: Average Annual Percent Change

6.4. Crude Oil Prices

The crude Oil market was fairly stable from the late 1940's until 1973. Since then, crude oil prices have experienced changes, reacting to market forces. In 1973, the Arab Oil embargo presented the world with its first major energy crisis. Crude oil prices rose sharply as Arab producers cut world supply. The Iranian revolution in 1978 gave the world oil market its second major shock. In late 1978, an oil field strike in Iran halted production there. The lack of exports cut the world supplies and the price of oil again increased greatly. When the Iran/Iraq war started in 1980, prices increased again. Ten years later, Iraq's invasion of Kuwait began another sudden escalation of prices.

The Organization of Petroleum Exporting Countries (OPEC) has influenced world oil prices since it was organized in 1960. Originally created to negotiate production and pricing matters with major oil companies that at time had a large controlling interest in those countries supplies, OPEC now tries to keep prices at its target level by setting an upper production limit on its members. OPEC has the potential to influence oil prices worldwide because its members possess such a great portion of the world's oil supply.

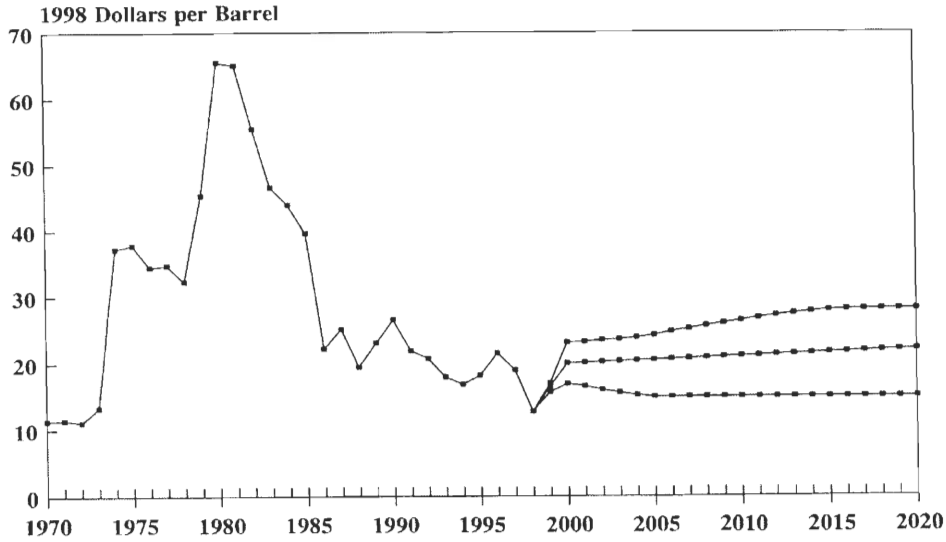
In 1982, world crude oil prices began a downward trend as demand slackened. Increasing production by non-OPEC countries, such as Egypt, Mexico, Norway, and the United Kingdom, created an oversupply of oil in the world market. When resurgence in OPEC production began in 1986, crude oil prices plummeted. In the years following the price collapse, prices fluctuated as world oil demand increased slightly, and OPEC continued to struggle to keep production within its agreed-upon limits.

On August 2, 1990, Iraq invaded Kuwait, causing crude oil and product prices to rise suddenly and sharply for the third time in 17 years. After the United Nation approved an embargo on all crude oil and products originating from either country, uncertainty about future supply caused the rapid price escalation. Between the end of July and August 24, 1990, the world price of oil climbed from about $16 per barrel to $28 per barrel. The price escalated further in September, reaching about $36 per barrel. By the end of November, however, as production from other countries offset the loss of Iraqi and Kuwait oil in world market, and fears of worldwide shortage subsided, petroleum prices stabilized.

Over the past 25 years, the oil prices have been highly volatile. In the future one can expect volatile behavior to recur because of unforeseen political and economic

circumstances. It is well to recognize that tensions in the Middle East, for example, could easily give rise to serious disruptions in normal oil production and trading pattern. From the business as usual point of view, and according to the DOE and EIA annual reports, the long-term price trajectory is expected to rise significantly due to the increase in the oil demand worldwide as mentioned in the previous sections.

Figure 10. History and Projections of the World Oil Prices, 1970-2020



Source: Energy Information Administration (EIA), Annual Energ Review 1999, DOE/EIA Washington, DC

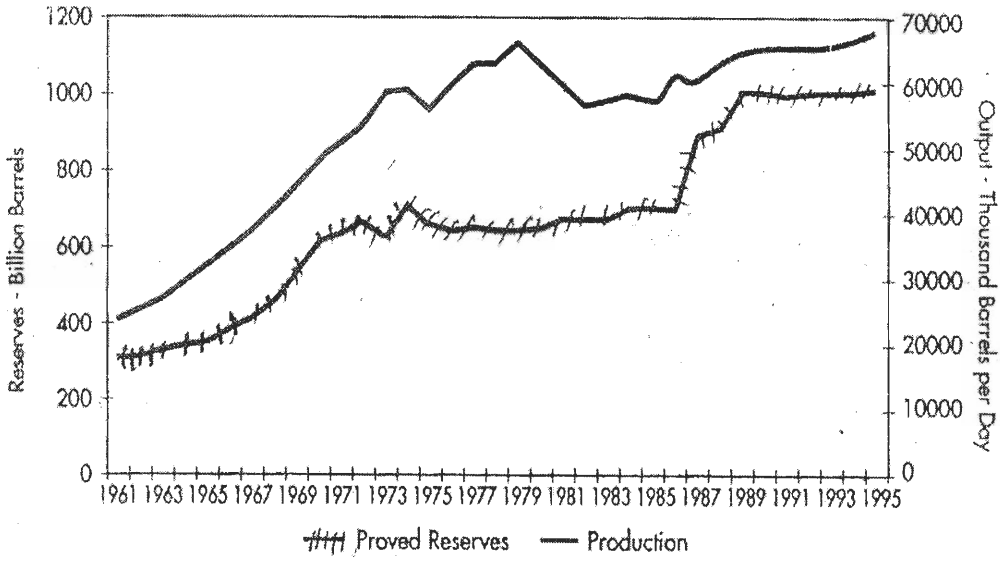
6.5. Petroleum Resources and Reserves

The future of oil production is ultimately determined by the quantity of remaining oil reserves and the recovery factor. It is therefore important to use reliable estimates of remaining oil reserves when preparing long-term oil supply forecasts.

The chart in figure 11, taken from the British Petroleum Statistical Review of World Energy, shows how estimates in this official world oil reserves and production have changed between 1961 and 1995.

An interesting feature of figure 11 is the bulk of the reserve revisions that took place between 1961 and 1995. Between 1985 and 1989, the worldwide oil reserves increased by 43 percent or 304 billion barrels up from 708 billion barrels in 1985. Such a huge increase raises the questions of why and where these revisions occurred.

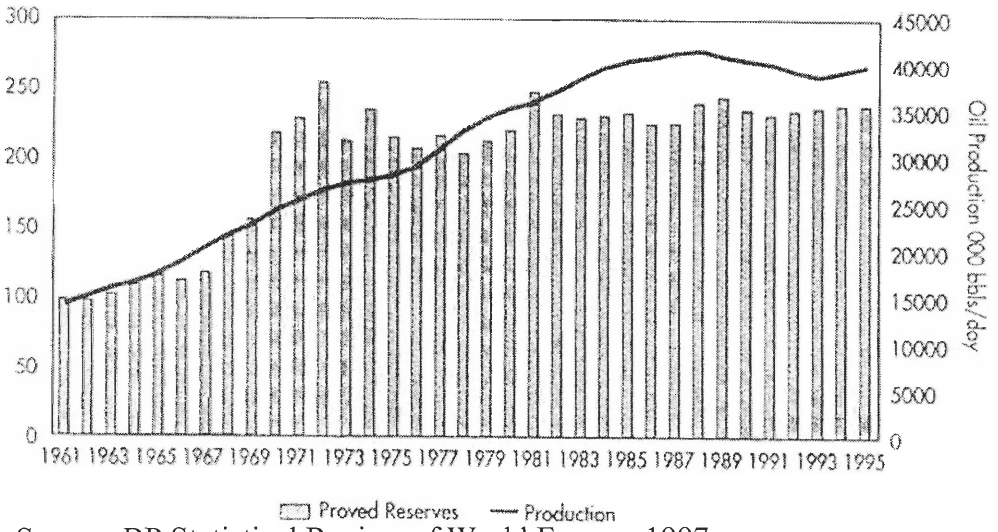
Figure 11. Estimate of the World Reserves and Production, 1961-1995



Source: BP Statistical Review of World Energy

In order to answer these questions, it is useful to divide the worldwide reserves between OPEC and non-OPEC countries. In figure 12, it is clear that non-OPEC proved reserves remained broadly stable during the period 1970 and 1995 at around 200-250 billion barrels.

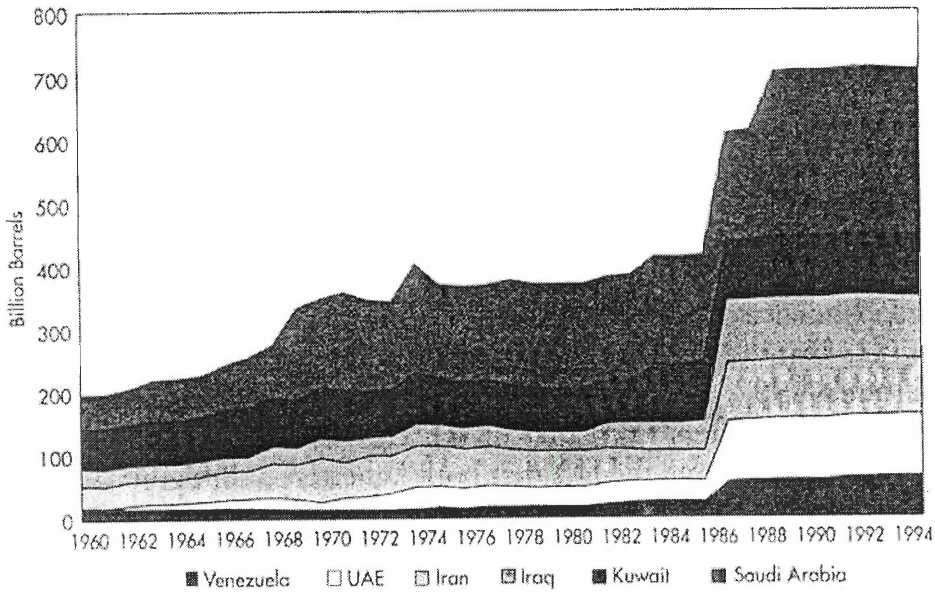
Figure 12. Non-OPEC Proven Reserves 1961-1995



Source: BP Statistical Review of World Energy, 1997

The dramatic increase in reserves took place in the OPEC area (figure 13). Total OPEC official oil reserves increased by almost 300 billion barrels between 1985 and 1989. In the space of just four years, total OPEC oil reserves increased by 62 percent since then, OPEC's total reserves have remained practically the same.

Figure 13. OPEC Official Reserves, 1960-1994

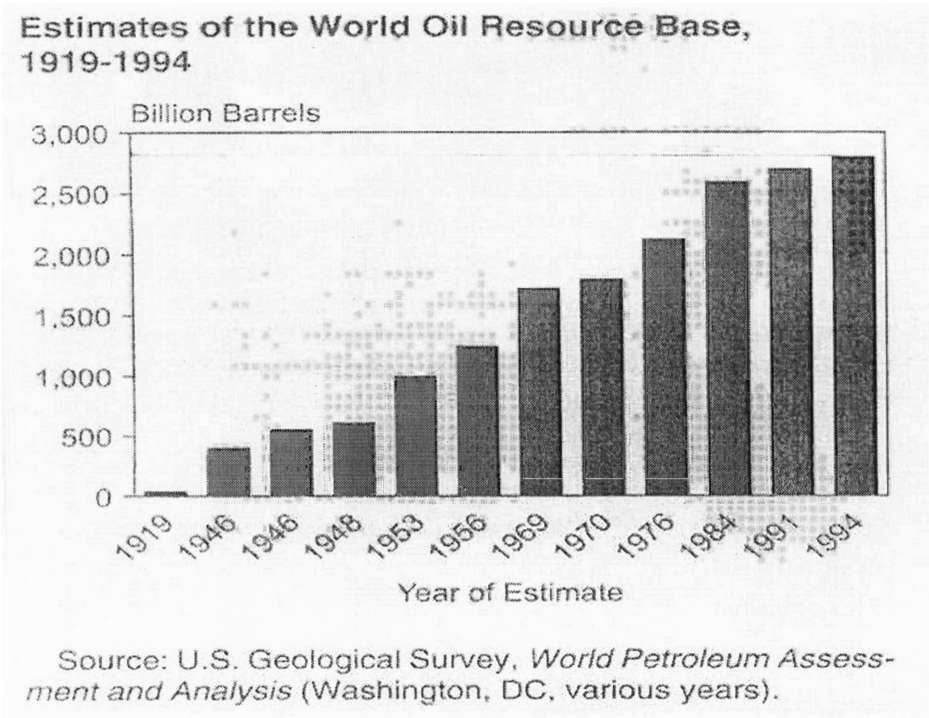


Source: BP Statistical Review of World Energy, 1997

Because of this large increase in the estimate reserves, and since reserves were an important factor in determining quota allocations; many commentators have questioned the reliability of the reserves claimed by the OPEC members. Further more large quantities of unconventional oil also appear to have been included in some OPEC member country estimates, possibly in order to obtain a large oil production quota *(IEA 98)*.

In this regard, it is instructive to look at the estimates of ultimately recoverable oil resources put together by experts within government, industry, and academia. Such efforts have been coordinated periodically by the U.S. Geological Survey (USGS) of the U.S. Department of Interior in its World Petroleum Assessment and Analysis. The most recent USGS assessment of worldwide oil resources (1994), estimated ultimate recoverable oil resources in the range of 2.1 to 2.8 trillion barrels (figure 14).

Figure 14.



Source: U.S. Geological Survey, *World Petroleum Assessment and Analysis* (Washington, DC, various years).

Currently, cumulative production (Resources which have already been discovered and produced) and estimated reserves (Recoverable resources which remain to be produced) are both approximately 800 billion barrels, implying undiscovered oil resources in the range of 0.5 to 1.2 trillion barrels (*DOE, 1999).*

The most of the world's reserves are located in the Middle East. Saudi Arabia has more crude oil reserves that any other nation. About two-thirds of the world's proved reserves (Reserves which are expected to be recoverable in the future under existing technological and economic situation) of crude oil are located in countries which belongs to the Organization of Petroleum Exporting Countries (OPEC) (table 7)

Table 7. Estimated Undiscovered and Ultimately Recoverable Conventional Oil Resources as January 1, 1993 (Billion Barrels)

Region	Undiscovered Oil Reserves		Cumulative Production	Identified Reserves	Ultimate Resources	
	Low Estimate	High Estimate			Low Estimate	High Estimate
OPEC	**95.3**	**319.8**	**282.9**	**706.4**	**1,084.6**	**1,309.1**
Persian Gulf	74.2	232.0	177.0	583.0	834.2	992.0
Other	21.1	87.8	105.9	123.4	250.4	317.1
Non-OPEC	**196.9**	**685.4**	**415.7**	**396.8**	**1,009.4**	**1,497.9**
OECD	68.4	223.9	225.4	156.4	450.2	605.7
Eurasia	77.5	330.6	142.3	163.7	383.5	636.6
Rest of World	51.0	130.9	48.0	76.7	175.7	255.6
Total World	**292.2**	**1,005.2**	**698.6**	**1,103.2**	**2,094.0**	**2,807.0**

Source: C. Master, E. Attanasi, and D. Root (U.S. Geological Survey), *A World Petroleum Assessment and Analysis*,@ Proceeding of the Fourteenth World Petroleum Congress. DOE/EIA, *Petroleum: An Energy Profile 1999.*

Although there are relatively few giant oil fields in the world, they account for most of the world's oil reserves. Saudi Arabia has the world's largest known oil field, the Ghawar Field, which was discovered in 1948 (table 9). Ultimate resources of this field are estimated at 123 billion barrels of recoverable crude oil, of which 48.9 billion barrels have already been produced. As of 1984, there were 265 world-scale "giant" oil fields, 18 of which contained 10 billion barrels or more of recoverable resources (DOE, 1999).

Table 8. Distribution of Crude Oil Reserves and Production

Area/country	Percent of World World Reserves	Percent of Production
North America United States	7.28 2.01	18.11 10.74
South America Venezuela	7.33 5.82	8.20 4.17
Europe United Kingdom and Norway	3.28 2.91	9.38 8.1
Former Soviet Union	17.15	11.84
Africa Nigeria	6.35 1.54	10.73 3.06
Middle East Saudi Arabia	53.69 23.32	30.69 12.86
Asia-Ocean	4.75	11.04

Source: DOE/EIA, *Petroleum1996.*

Table 9. The World's Largest Proven Crude Oil Reserves

Country	1996 Reserves (million of barrels)
Saudi Arabia	261,444
Iraq	112,000
United Emirates	97,800
Kuwait	96,500
Iran	92,600

Source: OPEC, *Annual Statistical Bulletin 1996*

6.6. The Future of Oil Reserves

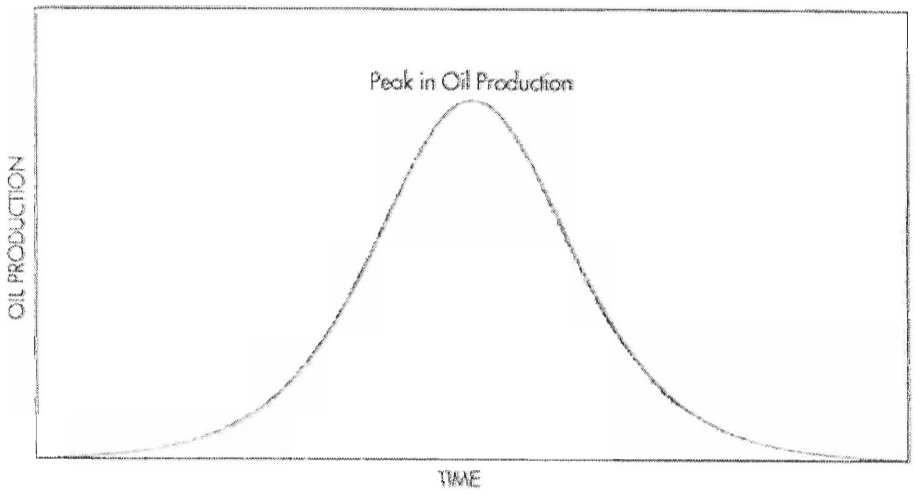
There are two main views in how to project the future of conventional oil supply, the pessimists' view, which makes a static assessment of reserves, and the optimists' view, which employs a continuous upward reappraisal of recoverable reserves.

6.6.1. The Pessimists' View

The pessimists treat the estimate of remaining reserves as a casual picture of the situation today with little or no anticipation of new information and technology that may be available over time. Advances in new technology are seen as increasing the rate of production while having a little impact on the estimate of recoverable oil.

They also assume that regional and global oil production follows a Hubbert curve (Figure 15) in which oil production peaks when half of ultimate oil reserves has been produced.

Figure 15. Generalized Hubbert Curve



6.6.2. The Optimist' View

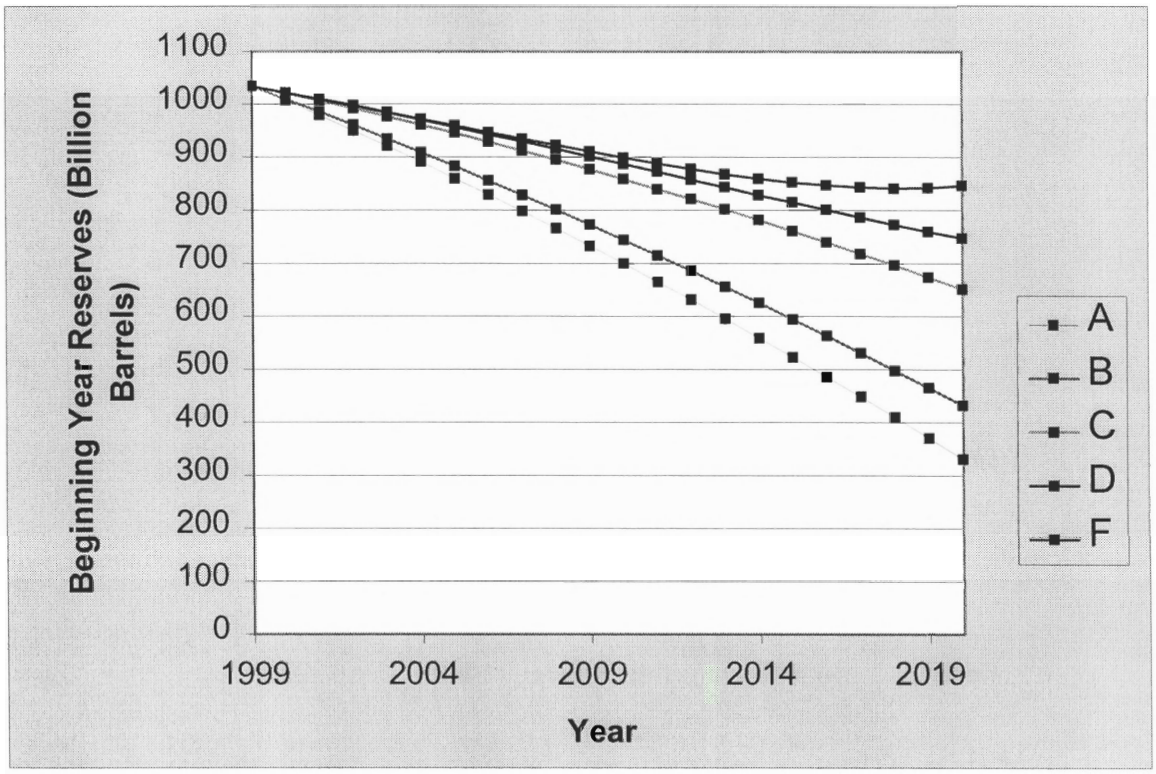
The optimists emphasize the roles of the technology, new information, and the oil prices on ultimate oil reserves. They believe that reserve growth from oil fields already discovered can occur from an increase in the recovery factor. Currently, the average worldwide recovery rate is less than 35 percent, technologies now being applied in North Sea and by many major U.S. producers regularly provide recovery rate in excess of 50 percent. If 50 percent recovery were to become the worldwide average, more than 750 billion barrels of conventional oil would be added to reserves (*DOE, 1999*). Where the pessimists assume that the future recovery factor is unlikely to increase significantly. The optimists also hold that some oil fields that already discovered but previously considered uneconomic because of their size or location can become economic through the application of new information and technology. Canada has cut the production costs for oil from tar sands to less than $10 per barrel. The recoverable bitumen from Canada and the heavy and extra-heavy oil from Venezuela are estimated to be at least 1 trillion barrels. An addition 15 trillion barrels of oil from the shale is estimated worldwide, more than one-third of which is located in the United States. The technology to extract oil from shale exists but remains prohibitively expensive at least in the context of the short term. In the long-term, however, as technology development improves the economic exploiting such unconventional crude oil resources, the unconventional could eventually become conventional (*DOE, 1999*).

6.7. Are We Running Out of Oil?

In 1885 the U.S. Geological Survey predicted "little or no chance of finding oil in California." In 1914 the U.S. Bureau of mines forecast a ten-year supply of oil in the United States. In 1972, a group of prominent experts known as the club of Rome wrote, the "Limits to Growth" report. They claimed that only 550 billion barrels of oil remained and that we could run out of oil by 1990.

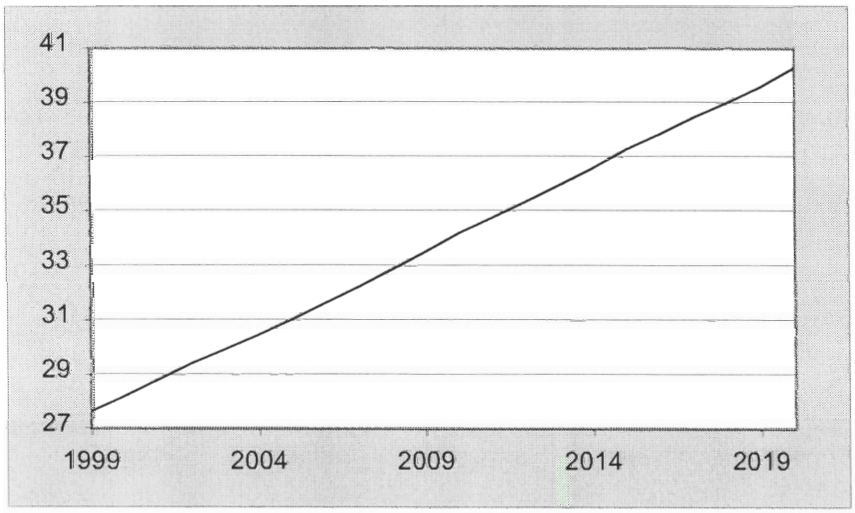
The latest scarcity theorists are exemplified by one of the world's most prominent petroleum geologists, Colin Campbell. He has argued in many industry and scientific journals that growing global consumption of oil, driven by the emergence of a modern, industrialized Asia-Pacific, is dramatically raising demand leading the prices to escalate and cause another energy crisis. By 2003, global production will peak and the oil age will start to end (Amy Jaffe and Robert Manning, *2000*). In fact, the world consumed 600 billion barrels of oil between1970 and 1990, and there are today more than a trillion barrels proven reserves (recoverable at current prices under current conditions). The International Energy Agency says that there are 2.3 trillion barrels in remaining ultimate recoverable reserves, and if unconventional resources such as tar sands and shale are included, the number may well be greater than 4 trillion barrels. Therefore, all the indexes show that the future of oil in the next two decades is very promising. Oil will remain the world's single most important source for energy in the foreseeable future and the key constraint on the oil demand and supply to 2020 will depend upon the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

Figure 16. World Oil Reserves 1999-2020



Source: DOE/EIA, International Energy Agency 1999
A - crude oil only
B - adjustment for natural gas liquids and refinery gain
C - adjustment for undiscovered oil (USGS low estimate)
D - adjustment for exploration technology and price
F- adjustment for extraction technology, price, and adjustment for unconventional liquids production

Figure 17. World Oil Demand per year 1999-2020 (billion barrels)



Source: DOE/IEA, International Energy Agency 1999

7. Organization of Petroleum Exporting Countries (OPEC)

The world market for energy is dominated by petroleum. Oil is the world's principal fuel; it is easily transported, and since production is concentrated in a few nations, most industrial nations are heavily dependent on supplies from abroad. Coal, on the other hand, is not only less heavily used, it is also more widely distributed throughout the world, and a higher proportion of countries can supply part of all of their needs. As for natural gas, the cost and difficulty of transporting it overseas inhibits trade (Griffin and others, 1982).

During the 1970s the importance of oil in international trade tripled, and the structure of the world market was radically changed. By 1980, energy (primarily oil), accounted for 21 percent of the value of world trade, compared to 7 percent in 1970; oil alone made up 31 percent of all goods imported by the United States (Griffin and others, 1982).

7.1. The History of OPEC

Before 1973 the focus of the world oil trade was on the so-called seven sisters: Exxon, Standard Oil of California (Chevron), Texaco, Royal Dutch Shell, British petroleum, and Gulf. These giant multinational oil companies controlled almost all the important international reserves outside the United States and Soviet Union. In most oil-rich countries, the government had long ago granted concessions to the companies, giving 2them exclusive rights to explore and produce oil within a defined area. The companies were, in effect, owners of the oil. They determined how much to produce, how much to pay the foreign government and what price to charge for the final product. The major

international oil companies effectively controlled the market in the non-Communist world (Ghadar, 1977).

By the late 1950s, however, they faced growing competition from independent companies and cut their prices. Persian Gulf countries where the Seven Sisters extracted oil were faced with falling revenues. On Sept. 14, 1960, representatives of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela met in Baghdad, Iraq, and founded the Organization of Petroleum Exporting Countries (OPEC) (Kubbah, 1974). OPEC was born of protest against the highhandedness of the major international oil companies – the Seven Sisters – which had created 'states within states' in the oil producing countries, controlling the amount of oil extracted, how much and to whom it was sold and at what price. On these vitally significant maters, the countries were never consulted. While the companies built huge financial empires at the expense of the producing countries, the latter received a meager royalty (Ghadar, 1977).

OPEC's principal objectives in the document registered at the UN Secretariat in 1962 were declared to be (1) to coordinate and unify the oil policies of member countries (2) to determine the best means of safeguarding their individual and collective interests (3) to seek ways and means of ensuring the stabilization of prices in international oil markets with a view to eliminating harmful and unnecessary fluctuations (4) to provide an efficient, economic and regular supply of petroleum to consuming nations and (5) to obtain a fair return on capital to those investing in the oil industry (Amuzegar, 1999).

In the early 1960s, the fledging cartel froze oil prices the same year to prevent further erosion in oil revenues. Other producer nations joined OPEC, including Qatar, the United Arab Emirates in the Persian Gulf region, as well as Algeria, Indonesia, Libya

and Nigeria. Membership in the organization enabled these countries to set a minimum royalty to be paid by companies for the privilege of extracting oil from their territories. The organization's expansion also helped the Seven Sisters by making it harder for independent companies to undercut them in the host countries (Samman, 1986).

The new order in oil development began to unravel in 1969 when Libyan strongman Muammar el-Qadaffi forced Occidental Petroleum, an independent American operator in Libya, to cut production. Because Libyan oil was of high quality, it was in high demand, and the cutback created an oil shortage. OPEC decided to profit from the change by raising oil prices. In an effort to stabilize the market, OPEC and the oil companies agreed in 1971 to a new pricing system that allowed prices to be negotiated every five years. OPEC's new pricing quickly fell apart. However, oil was bought from companies in the open market for more than the established price, and OPEC members wanted to share in the profits. Since then, governments of the oil-producing states have set production levels and prices. Their own national oil companies, along with companies owned by the governments of oil-importing nations (such as the British Petroleum (BP), Italy's ENI, and so on), have handled a large portion of international trade. Most of the oil in world trade has moved at prices based on, or linked to, those charged by the producing countries' international organization, OPEC (Samman, 1986).

Several factors contributed to this shift in the balance of power from the oil companies to the producing countries. The fundamental one was the growing world demand for oil. When there was excess capacity before 1973, the multinational companies were in a strong bargaining position. They could usually obtain supplies elsewhere if a particular government demanded an increase in royalties. With the decline

in American production, however, and the increase in world demand, this was no longer true after 1970 (Amuzegar, 1999).

The power of the major companies was also eroded by the rising importance of the smaller "independent" companies, some of them owned by governments of industrialized importing countries. These companies, which were less likely to have several sources of supply, were more easily pressured by the producing countries than the majors, who had to worry that giving in to demands in one country would inevitably lead to calls for similar concessions by other governments. The state-owned companies were often even more willing to pay higher prices because the political cost of breaking established trade ties outweighed the cost of price increase.

A final factor was the rise of nationalism in the producing countries. More and more, governments were under pressure to reduce the power and influence of foreign companies, and they responded by nationalizing the oil companies in the early 1970s (Amuzegar, 1999).

7.2. Energy Crisis of the 1970s

In 1971, OPEC and the oil companies agreed to a new pricing system that allowed for prices to be negotiated every five years. However, OPEC's new pricing system quickly fell apart since oil was sold by the companies in the open market for more than the established price, and OPEC members wanted to share in the profits. After the companies balked at their request, OPEC unilaterally raised the official price by 70 percent in October 1973, to $5.11 a barrel. The same month, the Arab producing

countries imposed an oil embargo on the United States and the Netherlands for their support of Israel in the Yom Kippur War.

The 1973 Arab embargo served as the catalyst in changing the oil market. It irreversibly loosened the grip of the major companies. Led by Saudi Arabia, several producing countries issued orders for sharp cuts in production, which the multinational companies obeyed. Subsequently, all OPEC members raised prices significantly. By the end of 1974 the price of crude oil had quadrupled over the period of a year, reaching nearly $12 per barrel leading to the decade's first oil shock.

The second shock came in the winter of 1978-79 following the Iranian revolution, which led to the ouster of Shah Mohammed Riza Pahlavi and his replacement by the Ayatollah Ruhollah Khomeini's militant Islamic regime. The revolution caused a disruption of oil from the Persian Gulf that was compounded by the outbreak in 1980 of the Iran-Iraq War (Griffin and others, 1982). By January 1981, OPEC's oil price had reached $34 a barrel, more than 10 times the price in 1972, before the first oil shock. Taken together, the shocks produced a windfall for OPEC members, whose oil revenues skyrocketed from less than $23 billion in 1972 to more than $280 billion by the end of the decade (Ghadar, 1977).

7.3. The Oil Market in Recent years

Since 1974, the producing countries have dominated the international market, and the influence of the largest multinational companies has been weakened. However, producing countries are not impervious to a decline in the world demand for oil, as the glut of 1981 and 1982 and the subsequent price cut has shown.

Of course, OPEC's price-setting ability is also limited by the different objectives of its diverse membership, and its price-setting meetings are sometimes acrimonious. Some members, such as Saudi Arabia, the United Arab Emirates, and Kuwait, have large oil reserves and small domestic populations (Table 12). They are comfortable with the prevailing level of revenues, and they can afford to take a moderate pricing stance. They tend to be more concerned about the long-term value of their oil. Others, such as Algeria, Nigeria, and Venezuela, have smaller reserves and large populations. They usually want to raise prices in order to meet pressing revenue needs and let others lower output as necessary to sustain the higher prices. Since their oil reserves may run out in twenty to twenty-five years, compared to Saudi Arabia's which are likely to last much longer, they do not worry excessively about the price of oil in the long term (Griffin and others, 1982).

The market power of the biggest producer, Saudi Arabia, enforces a degree of stability on the OPEC members. The Saudis produced nearly half of OPEC's output in 1981 and, partly for that reason, their "Arabian light" crude oil is considered the OPEC reference point or "marker." That is, other crude oil is priced in relation to it. Crude oils from different wells are often of different qualities, with the lighter, low sulfur crudes of North Africa and the North Sea usually considered the best since it's the easiest to refine into the most profitable mix of products. For this reason, producers of higher quality oils charge a premium above the marker crude price. In practice, the higher quality of some oils makes them worth as much as 10 percent per barrel more than the Arabian light oil. Differences in location and transport costs also contribute to price differentials.

However, many OPEC countries, as a result of domestic political pressure, at times price oil significantly more than 10 percent per barrel above the Saudis. In November 1981, when OPEC official prices were allowed to range between $34 and $41 per barrel, prices ranged from $32 in Saudi Arabia to $40 in Algeria (Griffin, 1982), (Samman, 1986).

The increased influence of the government is evident in almost every producing country. Saudi Arabia, for example, controls vast reserves that were once the property of the Arabian American Oil Company (ARAMCO), a consortium comprised of Exxon, Mobil, Texaco, and Standard Oil of California. The Saudis tell the ARAMCO partners how much to produce and how much they will able to buy for their own use. A government-owned company now sells a substantial portion of Saudi oil directly to other governments or companies. OPEC nations now own outright about 80 percent of their resources. Ownership of reserves by multinational companies outside the United Sates and Canada is primarily limited to areas such as the North Sea.

In addition, importing countries are also relying less on the multinationals. Feeling they may be able to make better deals by direct negotiation, governments of importing countries have also formed their own companies. These act largely as purchasing agents, although occasionally they participate in exploration and development of reserves, both at home and abroad (Samman, 1986) (Ghadar, 1977).

Many Western European nations and Japan acquire well over one quarter of their imports directly through government-owned companies or in deals in which the importing government is deeply involved. This percentage (over 25 percent of their imports) is increasing rapidly, while the role of multinational has declined.

Government-to-government deals introduced new political considerations into the oil market. Saudi Arabia has sold oil to Denmark on the condition that the Danes would not say anything the Saudis objected to about the political situation in the Middle East. Nigeria nationalized British Petroleum's operations because it objected to British policy in Southern Africa. And industrialized countries have been asked to make substantial investments in producing countries as part of oil sales agreements (Samman, 1986) (Ghadar, 1977).

The nature of international trade in oil has also changed in another way. The increasing number of players in the industry has led to an active open market for oil. Formerly, only small amounts of oil were traded openly because the major companies controlled the supply and refined and sold most of the oil they produced. Now more government-owned and smaller companies are involved. Many producers allocate their oil to centers of trading in Rotterdam, Singapore, and New York and sell to the highest bidder. A competitive market has risen alongside the OPEC-dominated major oil market. Several companies and countries rely on this market for the bulk of their purchases.

Because of developments over the past decade, attempts to control or predict the behavior of the world oil market are exceedingly difficult. Following the cutoff of Iranian exports in 1979, the United States and other industrial countries made efforts to reduce the competition for oil on the "spot market" where transactions not covered by long-term contracts are carried out, but could only watch in frustration as private companies bid up prices to unprecedented levels. Similarly, OPEC's attempts to unify prices have been frustrated by the ease with which member countries divert supplies to

the spot market to get higher prices or offer relaxed credit terms to attract buyers when sales are slow.

Thus, the OPEC was the dominant influence in the world oil market for a decade. The effectiveness of its collective decisions was modified by defections of individual member countries, the rise of an international spot market, the persisting influence exerted by the multinationals, largely because of their expertise, and major shifts in world economic conditions, which sharply alter the demand for oil worldwide. In short, despite its success in driving up prices in the 1970s, OPEC was not all-powerful. And it has remained subject to inside and outside political and economic pressures.

These pressures affect not only OPEC's market power, but also its long-run viability. Historically, they have been attempts to form international cartels to control output and prices in many industries, such as chemicals and metals. The degree of success has varied. Held together by certain common concerns, countries participating in these agreements have also been pulled apart by differences in their own national interests. For a decade, OPEC nations maintained a strong cohesion – greater unity than many experts had predicted. How long they will continue to hold together, given the strains that have already been visible, is difficult to guess. The era of domination by multinational oil companies was replaced by the era of OPEC, and in the flow of history it would not be unusual for OPEC, too, to be succeeded by another marketing arrangement.

Meanwhile, OPEC continues to exist presumably because member countries are convinced that they can obtain a greater return on their production of petroleum with it than without it. No one knows precisely how much higher prices are, and how much

lower production is, because of OPEC. No one knows what the level of output and prices would be today if oil could be produced and marketed under the conditions of truly competitive market (a type of world market, incidentally, that has never existed for oil). But no one doubts that in the 1970s OPEC succeeded in dominating the world oil market, sharply increasing the revenues of member countries (Samman, 1986).

7.4. OPEC's Role in the Future of Energy

In the first quarter of 1998, oil prices dropped until they reached a 12-year low in December of 1998, despite two rounds of output cuts by the member-states of the Organization of Petroleum Exporting Countries. Since then, however, the price of West Texas Intermediate has almost doubled as a result of OPEC's third round of cuts. Sheikh Ahmed Zaki Yamani, chairman of the Center for Global Energy Studies (CGES) in London, stated that at first sight, this might suggest that all the oil industry's problems have suddenly evaporated and that there is nothing more to worry about. He states "Why talk about oil price challenges when oil company cash flows are strong once more and OPEC's oil revenues are expected to rise this year (as in 1999) by $24 billion?"

He is of the opinion that the oil industry still faces serious challenges, notwithstanding the high oil prices seen in the third quarter of 1999. OPEC's actions have not really solved any of the deep-seated and long-standing problems that plague the industry. It is his opinion that OPEC-engineered oil price rises of 1999 have added to the industry's catalogue of worries (Oil & Gas Journal, Sept. 20, 1999).

The oil price rebound of 1999 has clawed back only a portion of the dramatic oil export revenue losses experienced by OPEC countries in 1998. OPEC's oil revenues

dropped by $51 billion (43 percent) in 1998 as a result of the 42 percent crash in oil prices. CGES estimates that OPEC will have regained only half of this loss in 1999, leaving a lot more to be done in 2000. The center also estimates that OPEC's oil revenues in 2000 will barely equal the $148 billion it earned in 1997, meaning that OPEC will be worse off than it was only three years ago (Oil & Gas Journal, Sept. 20, 1999).

OPEC has achieved a 43 percent increase in the price since April 1998 by shutting down almost 4 million b/d of oil production (total production is 27.69 Mb/d in 1998). Its excess capacity in 1999 is no less than 7.5 million b/d, representing 10 percent of world consumption. An astonishing 43 percent of this excess production capacity is held by Saudi Arabia, with another 40 percent attributed to Iran, Kuwait, the United Arab Emirates, and Venezuela (Oil & Gas Journal, Sept. 20, 1999, p. 24).

Recently, major oil exporters including Saudi Arabia, Venezuela, and Mexico agreed that more oil should be supplied to the market in order to ease prices. Final decisions are expected to be taken at the March 27 OPEC meeting in Vienna, Austria. Mexico's oil minister, luis Tellez, said to the "Investor's Business Daily" newspaper that his country might raise output at the end of the month even if OPEC decided not to do so (Investor's Business Daily, March 3, 2000).

The sensitivity of non-OPEC oil supplies to changes in the oil price is significant, and history has shown that OPEC disregards this fact. These predicted changes in output take time, however, which is why non-OPEC production's lack of immediate response is often misunderstood.

Most OPEC countries are planning to increase their own capacity, and a number of them are trying to encourage foreign companies to help them do so. Iran, Kuwait,

U.A.E., Libya, Algeria, Nigeria, and Venezuela all hope to expand capacity, expecting to add a combined 3.2 million b/d by 2005. Of these, the U.A.E., Algeria, Libya, and Nigeria already have a considerable foreign presence in their oil sectors, and Iran and Kuwait are seeking foreign involvement (Oil & Gas Journal, Sept. 13, 1999, p. 27; Sept. 6, 1999, p. 24). Iraq, on the other hand, should be able to increase its oil production capability by around 3 million b/d within 5 years of sanctions being lifted (Oil & Gas Journal, Sept. 20, 1999, p. 24).

OPEC's successful efforts to restrain production are keeping oil prices at 2-year highs and are expected to go higher but are also setting the stage for a recovery in non-OPEC oil supplies in the year 2000. The recovery, in turn, could undermine OPEC's recent success at restoring oil prices. In the longer term, however, the call on OPEC oil is likely to accelerate sharply as world oil demand resumes its upward march and non-OPEC supply depression sets in (Oil & Gas Journal, Sept. 20, 1999, p. 25).

7.4.1. Technology and the Recovery of Oil

Although many experts believe that oil will run out soon, other geologists and many economists put more faith in technology. "We're 30, maybe even 40, years before the peak," says oil geologist William Fisher of the University of Texas, Austin. Fisher has lots of support from the International Energy Outlook 1998 prepared by the U.S. Department of Energy's Energy Information Administration (EIA). "We don't see the peak happening until after the limit of our outlook," in 2020, says the EIA's Linda Doman. "We think technology and developing Middle East production capacity will provide the oil."

In the optimists' view, it doesn't matter that there are few if any huge new fields left out there to find. What does matter, they say, is how much more oil the industry can find and extract in and around known fields even as the world consumes 26 billion barrels a year. In their opinion reserves are growing rapidly. They argue that much of OPEC's reserve growth is real, and that OPEC and others are boosting reserves not so much through the discovery of new fields as through the growth of existing fields with the improvements in technology (Figure 16).

Three currently used technologies are helping drive this boost in reserves. Aided by supercomputers, prospectors are using the latest three-dimensional seismic surveying to identify likely oil –containing geologic structures, yielding a sharp picture of potential oil reservoirs. A second technology involves first drilling down and then sideways, punching horizontally through a reservoir so as to reduce the number of wells needed, and therefore the expense, by a factor of 10. Finally, technology that allows wells to be operated on the sea floor many hundreds of meters down is opening up new areas in the Gulf of Mexico, off West Africa, and the North Sea. Pessimistic economists, however, argue that the new technologies will make only slight changes to the production curves as discussed previously (Science, Aug. 21, 1998, p. 1130).

7.4.2. OPEC's Influence on Oil's Production and Prices

OPEC member countries produce about 40 percent of the world's crude oil and 14 percent of its natural gas. However, OPEC's oil exports represent about 60 percent of the oil traded internationally. Therefore, OPEC can have a strong influence on the oil market, especially if it decides to reduce or increase its level of production.

The oil and energy Ministers of the OPEC member countries meet twice every year to co-ordinate their oil production policies in light of market fundamentals, i.e. the likely future balance between demand and supply. The member countries, represented by their respective Heads of Delegation, may or may not set production quotas during these regular meetings and extraordinary meetings of the OPEC Conference. Given that OPEC is a major source of oil as mentioned earlier, OPEC's decisions to increase or reduce production may lower or raise the price of crude oil.

OPEC's impact on crude oil prices should be considered separately from the issue of changes in the prices of oil products, such as gasoline. There are many factors that influence the prices paid by end consumers for of oil products. In some countries taxes comprise 70 percent of the final price paid by consumers, so even a major change in the price of crude oil might have only a minor impact on consumer prices.

Traditionally, OPEC's market power has been viewed as a trade-off between maximizing price and maximizing market share. But given the group's dependence on steadily climbing oil consumption as witnessed by the Asian economic crisis's role in the latest oil price collapse and the stimulus that high oil prices gives to non-OPEC oil investment, the idea of deliberate supply curtailments designed to dramatically raise prices is a non-starter says Sarah Emerson, managing director, petroleum, for Energy Security Analysis Inc., Cambridge, Mass..

At the other extreme, the idea of raising production to lower prices and thereby shutting down non-OPEC output to seize market share also poses a problem. " In short, OPEC does not have the stomach to wield its power in this way – or it would have by now," Emerson said. "At the heart of it, OPEC's current spare capacity is concentrated in

only a few countries. As a result, there are too many countries within OPEC that suffer from low prices but cannot necessarily increase production to gain market share."

The consequence is that OPEC chooses to pursue a middle path by pursuing close management of stable prices, which ultimately puts it at odds with financial markets. "When OPEC makes big mistakes, like over-producing, in 1998, or takes strong action, like cutting production in 1999, it determines the general price direction," Emerson said. "The futures markets and their pure financial (non-commercial) players, however, can dramatically influence the pace and scope of that price move.

She also rejected as unrealistic such proposals before OPEC as setting price-band mechanisms to trigger changes in production or monitoring global stock levels to determine production policy. Emerson contends that, if OPEC wants price stability, it must embrace the other factors shaping price, understand them, and position itself through production decisions to avoid sharp drops or jumps in oil prices.

"In a sense, this means a renewal of the interseasonal quota-adjusting approach (used) back in the late 1980s and early 1990s," she said. "From 1994 to 1998, OPEC meetings were essentially opportunities to roll over or raise the production ceiling, or at least lift the official ceiling to the level of actual 'overproduction.'"

"The gradual return of Iraq and the Asian economic crisis, however, has ended the period during which OPEC can just keep letting production increase. Now, the pursuit of stable prices must once again entail cutting or raising production periodically or cyclically. The more OPEC tries to micromanage supply, the more vulnerable it will be to an overreaction in price." (Oil & Gas Journal, Sept. 20, 1999, p. 26).

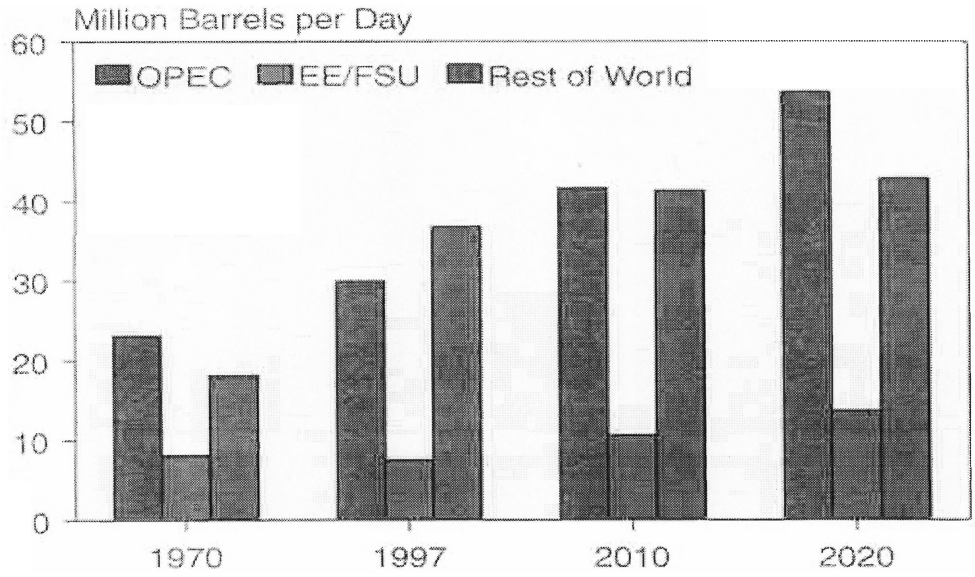
7.5. OPEC Oil Supply in the IEO99

Over the past two decades, the growth in non-OPEC oil supply has maintained OPEC's market share substantially under its historic high of 52 percent in 1973 (EIA/DOE, IEO99, Mar. 1999). New exploration and production technologies, aggressive cost-reduction programs by industry, and attractive fiscal terms to producers by governments all contribute to the outlook for continued growth in non-OPEC oil production.

North America dominated non-OPEC supply in the early 1970s, the North Sea and Mexico evolved as major producers into the 1980s, and much of the new production in the 1990s has come from the developing countries of Latin America and the non-OPEC Middle East as well as China. In the IEO99 reference case, non-OPEC supply from proven reserves is expected to increase steadily, from 44.1 million barrels per day in 1997 to 56.3 million barrels per day in 2020 (Table 11).

The reference case projection in the IEO99 anticipates that almost two-thirds of the increase in demand over the next two decades will be met by increase in production by members of OPEC rather than by non-OPEC suppliers. OPEC production in 2020 is projected to be almost 24 million barrels per day higher than it was in 1997 (Table 10 and figure 18).

Figure 18. World Oil Production in the Reference Case by Region, 1970-2020



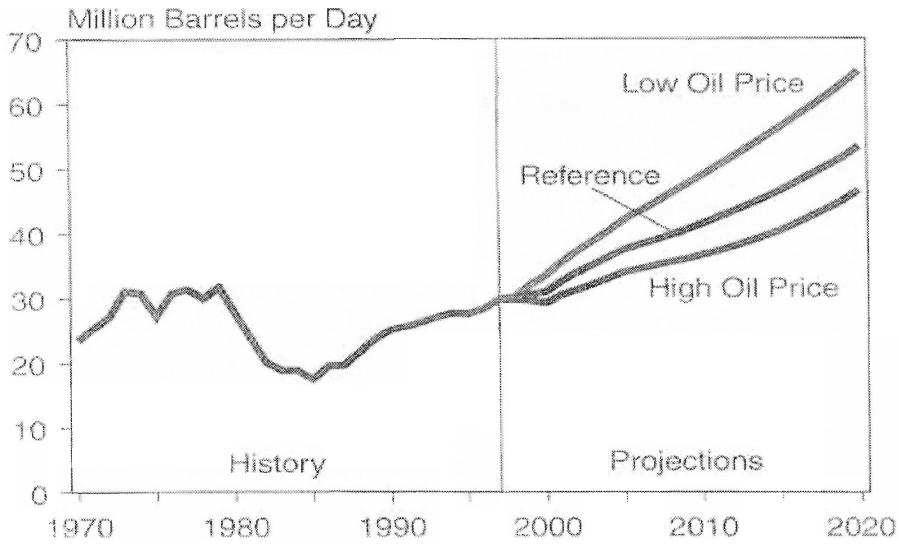
Sources: **1970:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database. **1997:** EIA, *International Petroleum Statistics Report*, DOE/EIA-0520(98/11) (Washington, DC, November 1998). **Projections:** EIA, World Energy Projection System (1999).

The IEO99 estimate of OPEC production capacity for 2005 is 37.6 million barrels per day, which is more than 4 million barrels per day greater than that projected in IEO98, reflecting an unexpected shift away from non-OPEC supply projects in the 1999 low-price environment to lower cost projects within OPEC areas. Some analysts suggest that OPEC might pursue significant price escalation through conservative capacity expansion decisions rather than undertake ambitious production expansion programs.

It is generally acknowledged that OPEC members with large reserves and relatively low production capacity expansion costs can accommodate sizable increase in petroleum demand. In the IEO99 reference case, the production call on OPEC producers grows at a robust annual rate of 2.6 percent (table 10 and figures 18&19). OPEC capacity

utilization is expected to increase sharply after 2000, reaching 95 percent by 2010 and remaining there for the duration of the projection period.

Figure 19. OPEC Oil Production in Three Oil Price Cases, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1996*, DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

Given the requirements for OPEC production capacity expansion implied by the IEO99 estimates, much attention has been focused on the oil development, production, and operating costs of individual OPEC producers. With Persian Gulf producers enjoying a reserve-to-production ratio exceeding 80 years, substantial capacity expansion is obviously feasible. Production costs in Persian Gulf OPEC nations are less than $1.75 per barrel. The capital investment required to increase production capacity by 1 barrel per day in Persian Gulf OPEC nations is less than $5,500 (IEO99). Assuming the IEO99 low price trajectory, total development and operating costs over the entire projection period expressed as a percentage of gross oil revenues are less than 20 percent. Thus,

Persian Gulf OPEC producers can expand capacity at a cost that is a relatively small percentage of projected gross revenues.

For OPEC producers outside the Persian Gulf, the cost to expand production capacity by one barrel per day is considerably greater, exceeding $10,000 in some member nations. However, even this group of producers can still expect margins in excess of 35 percent on investments to expand production capacity over the long term in even the low price case (EIA, Oil Production Capacity Expansion Costs for the Persian Gulf, DOE/EIA-TR/0606, Feb. 1996). Venezuela has the greatest potential for capacity expansion and has aggressive plans to increase its production capacity to 4.6 million barrels per day by 2005. It is unclear, however, whether the newly elected regime will support the outside investment that would be required for any substantial expansion of production capacity.

The reference case projection implies aggressive efforts by OPEC member nations to apply or attract investment capital to implement a wide range of production capacity expansion projects. If those projects were not undertaken, world oil prices could escalate; however, the combination of potential profitability and the threat of competition from non-OPEC suppliers argues for the pursuit of an aggressive expansion strategy.

Table 10. OPEC Oil Production, 1990-2020 (Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	24.5	------	-------
1997	29.8	------	-------
Projections			
2000	31.0	29.2	33.4
2005	37.6	34.0	42.0
2010	41.5	36.6	48.9
2015	46.7	40.4	56.3
2020	53.5	46.7	65.0

Note: Include the production of crude oil, natural gas plant liquids, refinery gain, and other liquid fuels.
Sources: **History:** Energy Information Administration (EIA), International Petroleum Statistics Report, DOE/EIA-0520(98/11) (Washington, DC, November 1998), Table 1.4. Projections: EIA, World Energy Projection System (1999).

Table 11. Non-OPEC Oil Production, 1990-2020 (Million Barrels per Day)

Year	Reference Case	High Oil Price	Low Oil Price
History			
1990	42.2	------	-------
1997	44.1	------	-------
Projections			
2000	45.7	46.2	45.2
2005	47.0	47.9	45.7
2010	51.7	53.1	49.6
2015	54.8	56.6	52.3
2020	56.3	58.1	53.5

Note: Include the production of crude oil, natural gas plant liquids, refinery gain, and other liquid fuels.
Sources: **History:** Energy Information Administration (EIA), International Petroleum Statistics Report, DOE/EIA-0520(98/11) (Washington, DC, November 1998), Table 1.4. Projections: EIA, World Energy Projection System (1999).

7.6. Non-OPEC Oil Supply in the IEO99

The estimates of non-OPEC production potential in the IEO99 are based on such parameters as numbers of exploration wells, finding rates, reserve-to-production ratios, advances in both exploration and extraction technologies, and the world oil price. In this decade, it is expected that non-OPEC producers will continue to increase output, producing an additional 7.5 million barrels per day by 2010 (Figure 18). Three factors are generally given the credit for the impressive resiliency of non-OPEC production: development of new exploration and production technologies, efforts by the oil industry to reduce costs, and efforts by producer governments to promote exploration and development by encouraging outside investors with attractive fiscal terms.

In the IEO99 forecast, North Sea production will exceed 8 million barrels per day when it reaches its peak in 2006. Production from Norway, Western Europe's largest producer, is expected to peak at about 4.1 million barrels per day in 2005 and then gradually decline to about 3.3 million barrels per day by 2020 with the maturing of some of its larger and older fields. The United Kingdom sector is expected to produce about 3.7 million barrels per day by 2005, followed by a decline to about 2.5 million barrels per day by 2020 (Table 11).

In North America, Canada's projected output increases by more than 200,000 barrels per day by the end of the decade, mainly from Newfoundland's Hibernia oil project, which could produce 150,000 barrels per day at its peak, some time near the beginning of this century. Canada adds an additional 600,000 barrels per day in output from a combination of frontier area offshore projects and oil from tar sands. Mexico is

expected to adopt energy policies that encourage the efficient development of its vast resource base, with expected production volumes approaching 4 million barrels per day by 2010 and showing very little decline for the remainder of the projection period. The U.S. falling output is expected to be more than offset by production increase in Canada and Mexico.

Oil production in the Former Soviet Union (FSU) is expected to reach 7.6 million barrels per day by 2005 (Table 11). There are delays expected in the startup of many Caspian Basin projects as well as a pessimistic outlook for investment interest in Russia. In the long term, however, output is expected to exceed 13 million barrels per day by 2020. Thus, by the end of the forecast period, the FSU would be a net exporter of more than 7.9 million barrels per day. China's oil production is expected to increase steadily to more than 3.6 million barrels per day by 2015, it will find itself importing large volumes of petroleum to meet growing domestic demand.

Oil producers in Central and South America have significant potential for increasing output over the next decade. Within five years, both Brazil and Colombia output are expected to exceed one million barrels per day. Colombia's output reaches 1.2 million barrels per day early this decade and remains at that level for the rest of the forecast period. Brazil output is expected to exceed 1.6 million barrels per day given a favorable climate for attracting foreign investment. Argentina is expected to raise its production levels by more than 100,000 barrels per day early this decade and could become a million barrels per day by 2005 (Table 11).

Several Western African producers (Angola, Cameroon, Chad, Congo, Gabon, and Ivory Coast) could eventually gain the benefits of substantial offshore exploration

activity when the oil price environment becomes more favorable. Angola is expected to more than double current output and to achieve stable production levels of at least 1.7 million barrels per day over the projection period. The other West African producers are expected to increase output modestly for the remainder of the projection period. North African producers (Tunisia and Egypt) produce from mainly matured fields, which are more than likely to be in gradual decline after 2000. Sudan is expected to produce almost 200,000 barrels per day early this century (Table 11).

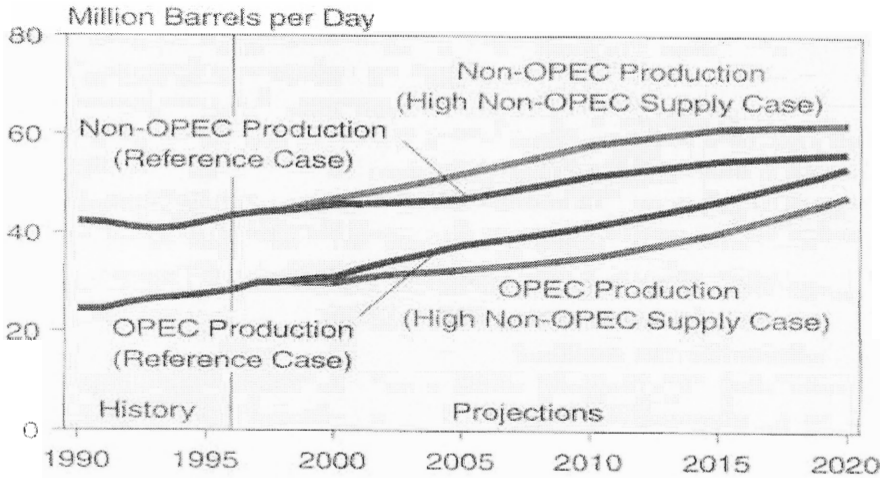
Oil producers in the Far East are beginning to reap the benefits of enhanced exploration and extraction technologies. India is expected to show a modest production increase into this decade and show very little decline in output thereafter. Deepwater fields offshore from the Philippines are expected to produce in excess of 200,000 barrels per day by 2004. Vietnam's output is expected to exceed 450,000 barrels per day by 2020. Australian production is expected to peak at about 920,000 barrels per day by the middle of this decade, but enhanced extraction technologies temper the production declines somewhat after 2005. Malaysia's output peaks at about 830,000 barrels per day by the turn of the century and declines gradually at about 650,000 barrels per day in 2020. Papua New Guinea achieves production volumes approaching 200,000 barrels per day by the middle of this decade, followed by a steady decline over the remainder of the projection period.

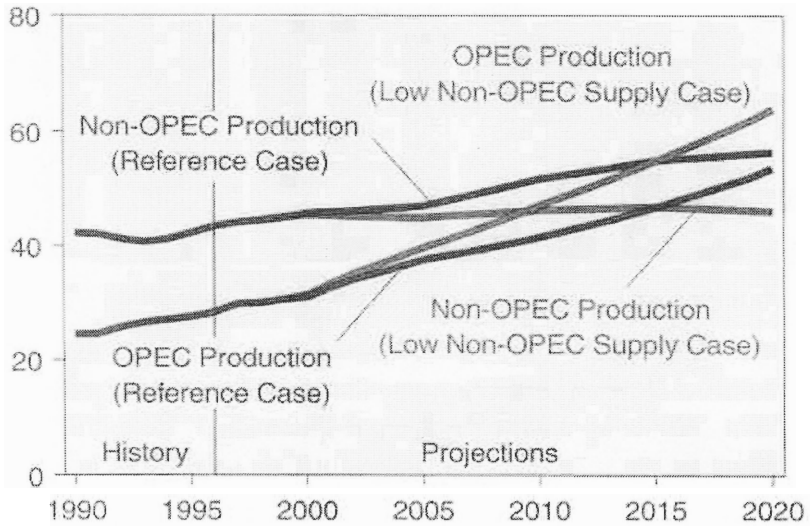
7.6.1. Alternative Non-OPEC Supply Cases

The only variable affecting the estimates of non-OPEC production potential in the alternative case described above is the world oil price assumption. As a result, the range

in non-OPEC supply could vary only slightly more than 4.6 million barrels per day at the end of the forecast period. Improved technology and better understanding of the underlying resource potential have been major factors sustaining non-OPEC supply in the recent past. Two additional cases—the high and low non-OPEC supply cases were developed for the IEO99 to examine those two factors. Figure 20 compares OPEC and non-OPEC production estimates in the reference case with those in the two alternative non-OPEC supply cases. The alternative cases used reference case assumptions except for the following departures.

Figure 20. OPEC and Non-OPEC Oil Production in Three Cases, 1990 - 2020





Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1996,* DOE/EIA-0219(96) (Washington, DC, February 1998). **Projections:** EIA, World Energy Projection System (1999).

High Non-OPEC Supply Case:

- Technology improvements over the forecast period are assumed to be transferable worldwide.
- One-third of the world's (non-OPEC, non-U.S.) undiscovered oil is considered economical to develop over the forecast period.
- Due to increased optimism regarding the offshore production potential in the FSU, Latin America, West Africa, and the South China Sea, undiscovered oil in those regions is assumed to be 15 percent greater than the estimates in the reference case.
- A reserve-to-production ratio of 15 years (slightly less than the current non-OPEC ratio) is used as a lower bound for production estimates.

Low Non-OPEC Supply Case:

- The amount of oil production from undiscovered reserves in deepwater areas is assumed to be 25 percent less than the reference case estimate as a result of persistent low oil prices and the finding of more natural gas deposits than oil deposits.
- There are assumed to be no significant technology improvements over the forecast period, and worldwide oil recovery rates are assumed to average only 35 percent.
- Only one-fifth of the undiscovered oil in non-OPEC areas is considered economical to develop over the forecast period.
- Russia's oil production is assumed to be one-third of that estimated in the reference case.

7.7. The Composition of World Oil Supply

Petroleum demand is expected to rise by an average of 1.9 percent in the next two decades; a large proportion of this increase is projected being met by the members of OPEC rather than by non-OPEC suppliers. With the low cost production (more than three-quarters of all OPEC reserves can be produced at a cost of less than $5 per barrel, and virtually all of the remainder can be produced for less than $10 per barrel) (Figure 21), and the reserve-to-production ratio, it is reasonable to expect that OPEC will accommodate sizable increases in petroleum demand.

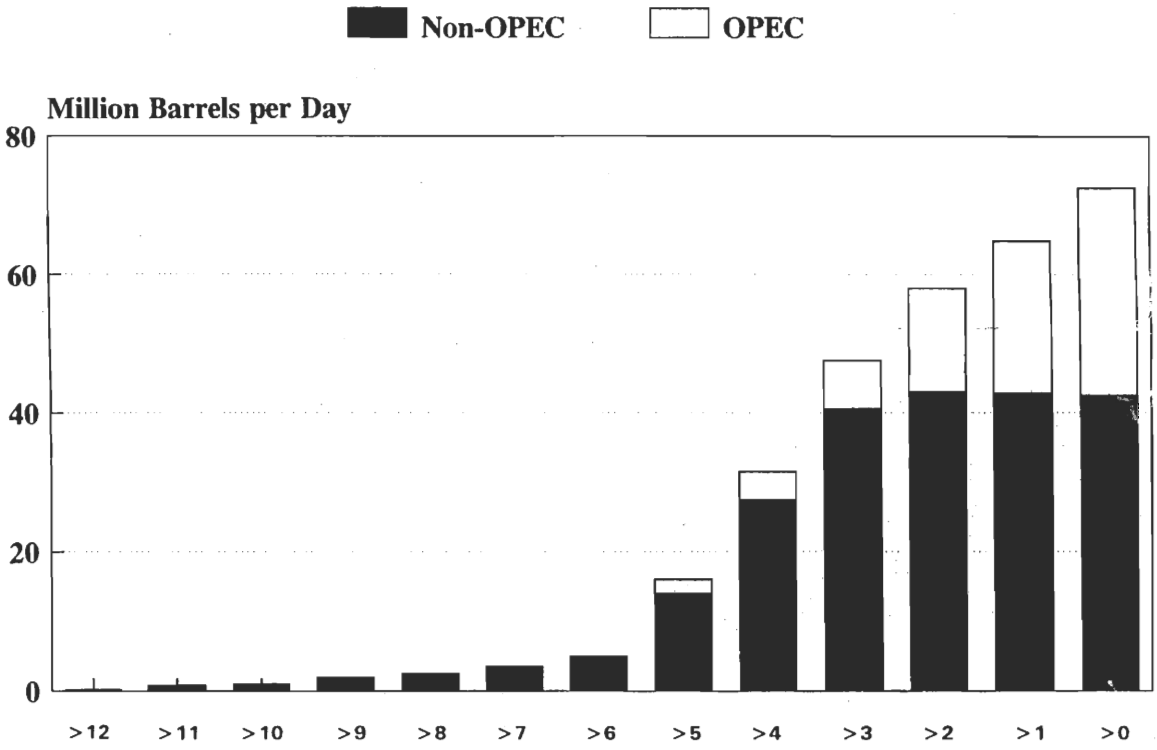
7.7.1. The potential of OPEC:

The table below shows the differences among the OPEC members regarding, population, reserves, reserves-to-population ratio, as well as production quota for each country. It is very clear that these countries have significant diversity. Saudi Arabia, the

United Emirates, and Kuwait have large oil reserves and small domestic populations, others, such as Algeria, Nigeria, and Venezuela, have smaller reserves and large populations. OPEC members also have different qualities of oil (African producers have a high quality oil), and differences in the geographical conditions that make the production cost vary.

In discussing OPEC's behavior as a major player in the energy market, it is very important to study the components that form this organization. Recent geological surveys show that the Middle East has the most of the world's reserves, they also indicate that two-thirds of the world's proved reserves of crude oil are located in countries that belong to the Organization of Petroleum Exporting Countries. It is essential to notice that all OPEC members are developing countries. Except for Venezuela and Indonesia, all other OPEC countries are located in the Middle East and Africa and most of them share the same religion, traditions, and language. In addition, some experts see that Venezuela and Indonesia will drop out of OPEC in the near future once their reserves are dried up due to their low reserve-to-population ratios compared to OPEC members (Table 12). Based on the Business As Usual Scenario, we think that the future is very promising for OPEC - as a homogeneous organization that is entirely Arab - to corporate and control the petroleum market supply in order to maximize their profits.

Figure 21. Marginal Operation Costs of Oil Production (1997 Dollars per Barrel)



Source: DOE, *International Energy Outlook, March 2000*

Table 12. The Distribution of Reserves, Production, and Population within the OPEC Members.

Country	1996 Reserves (million of barrels)	Oil Production (million barrels per day)	Population (million)	Reserve-to-Population Ratios	Percentage of World Population
Saudi Arabia	261,444	8.1	19.5	13407.38	0.32
Iraq	112,000	2.11	21.3	5258.21	0.35
United Emirates	97,800	2.63	2.3	42521.7	0.038
Kuwait	96,500	1.8	1.8	53611.11	0.029
Iran	92,600	3.6	71.5	1295.10	1.18
Venezuela	72,600	3.12	22.7	3198.23	0.37
Nigeria	22,500	2.1	118.3	190.19	1.96
Indonesia	4,979	1.36	203.4	24.47	3.37
Qatar	3,700	0.66	.568	6514.08	0.009
Algeria	9,200	0.82	29.5	311.86	0.49
Libya	29,500	1.39	5.78	5103.80	0.09
Total World	802,479	66.163	6,030.3131 3	N/A	100

7.8. Can OPEC Guarantee the Security of Oil Supply?

OPEC is not the only source of oil in the market, it does not control the market but rather it has a strong influence on the oil prices. Oil consumers need steady supplies of oil, and oil producers rely on steady demand. If demand changed suddenly it would have a major impact on the profitability of oil producers and the economies of many

countries around the world. In the World Energy Outlook, world petroleum demand is projected to rise at annual average of 1.9 per cent in the next two decades, causing oil requirements to reach 110 million barrels per day. Over the next decades, the reference case projections depict increases in demand this being met proportionately by increases in production by members of OPEC rather than by non-OPEC suppliers because of many factors that we discussed in the previous sections. The question that can be asked is whether OPEC producers will pursue such a strategy (increase production), or will they prefer instead to see oil prices escalate as demand increases.

High oil prices tend to be a double-edged sword. If prices get too high, that will tend to stifle demand and encourage consuming countries to take action to diversify and reduce energy supplies. On the other hand, the recent bout of depressed prices did not provide the oil industry with sufficient funds to invest in future needed supplies. To provide a steady supply with reasonable prices in the next twenty years, OPEC must implement a strategy of production capacity expansion through an intensive development in production and reduction operation costs among the OPEC members. In the International Energy Outlook, the reference case implies aggressive efforts by OPEC to apply or attract investment capital to meet a wide range of production capacity expansion projects. If those projects were not undertaken, world oil prices could escalate. If investors are unsure about the risks and the likely returns from petroleum investments, they may not make those investments. If they do not invest enough money, or do not do it far enough in advance, then the world could face a shortage of oil supplies and downward spiral in the global economy. A second factor relates to the threat of competition by the non-OPEC producers. Non-OPEC oil supply potential is now recognized to be quite

robust. Extensive exploration, improved technology, and government policies that encourage investment sustain expectations that non-OPEC supply expansion could displace or replace OPEC if OPEC efforts are not competitive. Moreover, all oil producers recognize that significant portions of the oil market are threatened by competition from other fuels, including oil from non-conventional sources and other energy substitutes (DOE/IEA 1995).

8. INTERVIEW

On the 12/05/1999, we have conducted an interview with Mr. George Daniel Butler, the expert in world oil markets at the U.S. Department of Energy in Washington D.C. We chose to conduct a qualitative interview in order to obtain some flexibility to adjust our later questions depending on how Mr. Butler answered our earlier questions. This would further clarify the responses and establish more solid answers to the issues discussed in the interview. The interview was recorded with the consent of Mr. Butler and later transcribed and edited to deliver to the reader the information discussed in the tape. This transcript is as accurate as the recorded interview.

Question: Do you think OPEC would dominate or drive the energy market in the future? And how do you compare OPEC's role in the market with non-OPEC producers?

Mr. Butler: I do not know if it's fair to say that OPEC will drive all energy markets in the long-term. It depends on technology more than anything else does. For instance, natural gas is produced and consumed within a fairly tight geographical region, however, if a more sophisticated technology is created to turn natural gas into a high quality transportation fuel, gas will become an awful important commodity. Iran, Qatar, and a few of the Middle East countries that belong to OPEC, as well as the former Soviet Union are rich in natural gas. Those areas will become enormously important if gas and oil technology become more refined. They are actually doing quite well right now; however, they are a little expensive.

As far as the near-term is concerned, we're seeing today that OPEC has still quite a lot of leverage in the market. They may be able to adhere to their production cutbacks like they've done often in the past; it does have a market effect on the world oil market especially on oil prices. We saw in the beginning of 1999, the lowest prices we've seen in twenty years. By December, we're going to see high prices in relation to what the year started out. The primary reason for that is that OPEC has been able to adhere to their announced production cutbacks. In addition, there are non-OPEC countries such as Russia, Norway, Egypt, and Mexico, which also agree with OPEC that some changes have to happen to the market and they agreed to the production cutbacks and adhered to those cutbacks as well as OPEC. It did have a market effect on the oil prices. Long-term wise, what we experienced in this whole decade is that the resiliency of non-OPEC

supply is something that people did not really predict during the 1980's, which openly said that non-OPEC production is about to stagnate or at the very best remain level into the 1990's while OPEC will be the major oil player in the world. Nevertheless, that did not come about. In fact the opposite was true, non-OPEC has maintained more than 50 percent of market share even until today. We even foresee until the next decade or so that OPEC will not gain more than 50 percent of market share. Technology probably was the biggest reason why that occurred. From the drilling side, you have horizontal drilling and 3D seismic. On the recovery side, average recovery increased from 35 percent in the early 1990's by about 5 percent which is an enormous amount of oil recovered from working wells as well as already used up wells. If that technology can be transferred into other areas, there'll be an enormous increase in oil recovery. Technology advances, company mergers, restraints on expenditure, and better management in oil companies have also contributed into a much more efficient fiscal regime in oil exploration and recovery. Therefore, the 90's showed that OPEC's predictions in the 80's about non-OPEC were not accurate. We feel that much is going to be repeated in the next twenty years as far as non-OPEC is concerned. This high price environment that we're looking at right now is temporary. We're going to reach a time when you'll have a large non-OPEC supply especially from the Caspian region, offshore West Africa, south China sea, offshore Latin America (Columbia and Brazil area), and Siberian sea. With the prices propped up, what traditionally happens, you have some non-OPEC production coming online and that starts diminishing OPEC's share in the market. That's when OPEC will start cheating. Right now with the low price environment, projects like the Caspian Sea and so forth are backed off because profits are eliminated due to the high production

costs relative to the oil prices in the market. Once the prices are in the mid $20's, activity increases in the non-OPEC arena. They start coming online and threaten OPEC. OPEC will produce more than their announced production cutbacks and hence the price will start to fall again.

What we'll see in the next twenty years or so is the cyclical type movement of prices. This type of movement is not seen in our forecasts because we don't try to produce cyclical type forecasts. We never forecast disruption in petroleum supplies. There could probably be two or three disruptions in petroleum supplies that will cause spikes in the oil price. There's clearly enough oil in the non-OPEC arena to have that situation where OPEC tightens their belt and prices rise which encourage non-OPEC supply to increase.

DOE/EIA does not predict running out of oil in the next twenty to twenty five years. A lot of people are feeling uneasy for whatever reasons they come up with. Their arguments are quite hollow, that something is going to start a decline in oil supplies in the 2020 period. With the new technologies [these technologies are mentioned in the OPEC's section], especially if oil technology improves dramatically by the end of this century.

Question: Do you foresee any major disruption in the energy market during the next two decades?

Mr. Butler: They would fall under the realm of disruption in petroleum supply because of a political event. We certainly acknowledge that those can occur and the Middle East being what some people view as a volatile region certainly could be the area which would

cause a real problem in the world oil market. Our forecast is a steady-state business-as-usual type forecast. It doesn't assume anywhere during the 2020 period to have problems similar to that. AEO (Annual Energy Outlook) and IEO (International Energy Outlook) are business-as-usual type forecasts and nowhere embedded in them are there any disruptions or political turmoil.

Question: What is Iraq's influence on the oil market?

Mr. Butler: I don't really foresee any problems with the change of regime in Iraq, unless it would be a more stringent or totalitarian type situation than it is now. But, for the oil market that would just mean a period where there will be a glut in oil supply and should be a very favorable price market for the world.

Iraq produces 3million b/d with the sanctions imposed. In case the sanction is lifted, the production would increase up to a 6 million b/d within a decade. Iraq has already made plans with China and Russia on the expansion of production capacity.

At this point of time, Iraq does not play a part in OPEC decisions or participate in production cutbacks since they have to produce up to the United Nations' sanction level and basically is the only game they can play. If sanctions are lifted, they can expand production. The questions are, will they? How much will they produce? And would OPEC countries ask Iraq to help them out with production cutbacks to keep the price propped up? Nobody knows if Iraq would do that or not.

Question: Does the Difference in the Reserve-to-Population Ratio among OPEC Members influence OPEC's Solidarity?

Mr. Butler: That's clearly a factor that would not surprise me. Initially, Indonesia drops out of OPEC, and eventually Venezuela drops out of OPEC for these reasons. Indonesia wouldn't even be an exporter of petroleum in five years; they'll consume it all if the economic growth projections for Indonesia are even close. Venezuela is very much the same. With their oil tied with the U.S. market and such it just makes them a completely different player than the rest of OPEC. *That's just a personal guess and not a DOE projection! (Says Mr. Butler)*

Except for Nigeria, West and North African countries (Algeria and Libya), if you got rid of Indonesia and Venezuela, you'll have an entire Middle Eastern Arab [OPEC]. However, it doesn't mean that they would entirely agree among themselves. It was clear from a conference in London that I recently attended that OPEC members showed differences in their long-term strategies. Most of it being as to whether to keep oil companies state-owned or invite outside investment opportunities.

Question: How would technology affect the future of oil market?

Mr. Butler: Not a long time ago, 35 percent of oil was recovered from any discovered well. However, developments in technology during the 1990's brought it up to 40 percent. How you produce it though is a different story. They might produce it all up front or conserve it for a later period if they thought prices are going up. That extra 5 percent is very significant.

Right now, reserves are a little over a trillion barrels. By increasing the so-called Proven Reserves by an additional 5 percent is an enormous amount of oil. Reserve estimates are based on this historic 35 percent recovery factor and if you could bring the rest of the world up to where the North Sea is, which is about 51 percent recovery, reserve estimates would shift dramatically. It's just a matter of the sophisticated equipment that is operating in the North Sea is not operating worldwide. The Middle East is not that sophisticated of an oil-producing environment as far as the equipment that they use. There's still many areas within the Middle East that are producing oil for a less than a $1 per barrel. It's that much of a natural flow, pressure, and a wonderful environment for oil production. They haven't had to go to that level of sophisticated recovery techniques to bring up the 35 percent natural recovery. If recovery is increased by 5 percent to 10 percent in the Middle East for the next decade or so, it would improve the Proven Reserves that were based on the historical 35 percent recovery.

Question: <u>What determines the oil prices?</u>

Mr. Butler: In 1997, OPEC's cost of producing a barrel of oil was about $6 or less. Whereas a fairly significant number of non-OPEC members produce oil at a cost of $10 to $11 per barrel. The reason is that non-OPEC members depend on offshore and deep-water production. Therefore, oil prices have to be high for non-OPEC countries to be able to produce oil.

The cyclical nature occurs when prices are high everybody can produce and the profits are high. Nevertheless, when prices are low, production stops or drops down until prices come up. There will be a high non-OPEC production when prices are high;

however, some of them have to drop out when prices drop down to the $10 to $13 per barrel. Non of the OPEC members has to drop out. That's why they have to show some restrain in their production in order to get the prices to come back up. That's where the cyclical nature comes about. OPEC always have higher profits due to their lower production costs than the non-OPEC countries.

Question: Do you consider OPEC as a Cartel?

Mr. Butler: I don't think they have ever really been a cartel in the classic definition of cartel. They clearly can exert a lot of pressure on the oil market especially if they cut back in production and can hold it there for a period of time. Likewise, they can send prices in the oil market plummeting if they don't show the power to be able to cut back on production, and they do have members that are producing well above their quotas. They clearly can make prices rise and fall. Because of that, there is a lot of resiliency in the non-OPEC environment which keeps OPEC out of being a classic cartel because there is another player out there that is responding to the OPEC decision. Which are sort of contrary to what OPEC would like to be the case. OPEC would like to have the power for prices to go up, stay up, and gain the benefits of that. They would also like this other entity known as non-OPEC not to have the ability to raise production and assume a larger share of the market and they have not been able to figure that out yet. It doesn't look like as I say the way technology has brought reserves in the non-OPEC arena over the last decade that they'll be able to exert that pressure on the market to keep prices high and to as well increase their market share.

It's to the advantage of non-OPEC countries to agree with OPEC on production cutbacks. This will bring the prices up and increase their profits. Norway, for example, agreed on production cutbacks with OPEC since they have a high production cost in the range of $7 to $9 per barrel which leads to higher prices and an increase in their profits.

Question: How would the conservation of energy has shaped the IEO99?

Mr. Butler: It's really hard when our forecasts only run to 2020 to make any comments on the conservation of energy, because we don't see an enormous amount of conservation in our forecasts with the predicted increase in consumption. We're bound in the U.S. and the rest of the countries of the world in our forecasts to lock in current legislation, which is one of the key assumptions in our forecasts. We cannot forecast any sort of conservation legislation like Kyoto or such in our forecasts. Therefore, anything that's not legislation right now does not go into the long-term forecasting. Since our outlook doesn't forecast legislation that will enhance conservation, it doesn't capture all the conservation that will probably occur over the forecast period.

Question: How do you compare the IEO99 with other forecasts provided by other agencies?

Mr. Butler: We're fairly consistent demand wise. Supply wise, the hierarchy in the IEA is much more attuned to those who think that oil supply, in particular, is in trouble in the post 2010 time period. They have the same level of demand as EIA, and they mention how much they expect OPEC and non-OPEC to produce. However, they predict a 12-13 million b/d shortfall that'll be produced somehow, but not sure how.

There is a disagreement that is more focused on geologists than anyone else is. There's a core of geologists who are very pessimistic about the outlook of undiscovered oil. All these forecasting tools make some sort of thought as to what undiscovered oil is, since predictions are based on the thought that more oil is to be discovered, and the key is how much oil will be discovered. That's where the differences of opinion among forecasters come from. In conclusion, IEA is much more pessimistic about the long-term outlook than the EIA.

Question: Do you see any significant increase in the share of other energy resources?

Mr. Butler: By 2020, natural gas would have increased its share of total energy. Coal would have declined because of tough environmental regulations. Nuclear is politically unpopular due to the waste disposal hazards. However, if technology to turn natural gas into liquid fuels comes about, natural gas will be a very important fuel and there will be a very significant increase in its share of the total energy market, since that will facilitate its transportation in oil product tankers. We also think that liquid fuel whether from oil or natural gas will still be the primary source of energy consumption well out toward the end of next century.

9. Conclusion

In 1960, when OPEC was founded, its members agreed that the organization's main target is to coordinate and unify their policies in order to assure fair oil revenues to their members and a steady supply of petroleum to the energy market (Section 7, pp. 50).

Since OPEC members have different resources, quality of oil, populations, and production cost, they face significant obstacles in coordinating policies and decisions in an attempt to bring a reasonable income to all members. Saudi Arabia, the United Emirates, and Kuwait, have large oil reserves and small domestic populations. They can be comfortable with the prevailing level of profits, and they can afford to take a moderate pricing stance. Those countries tend to be concerned about the long-term trends in the oil market. Others, such as Algeria, Nigeria, and Venezuela, have smaller reserves and large populations; they are usually looking for a high price environment in order to meet pressing revenue needs, and they tend to be worried about the situation of the petroleum market in the short term, since their oil reserves may run out in the next two decades. "... eventually Venezuela drops out of OPEC... they will consume it (oil) all."
Mr. Butler said.

As a cartel, OPEC members seek to agree on production quotas that would limit OPEC's total production of crude-oil and reach an optimal range of oil prices that will maximize their profits in the future. Furthermore, the optimal price range would allow OPEC to maximize profits, while keeping non-OPEC producers from increasing their market share.

In reality, it is difficult for OPEC to reach this optimal price range that would satisfy all of its members needs for profits due to the differences among these members

as mentioned earlier. "However, it doesn't mean that they would entirely agree among themselves. It was clear from a conference in London that I recently attended that OPEC members showed differences in their long-term strategies..." Mr. Butler said. Therefore, any production cutbacks by OPEC are likely to break down due to the tendency of some of its members to cheat in order to increase their oil revenues by taking advantage of the high price environment. To maintain their market share, other OPEC members may respond to this action by showing the same behavior (cheating), which would lead to a collapse of production agreements by OPEC.

Taking into consideration the heterogeneity among its members, it is possible that in the long run OPEC's production contract might collapse and lead to an unorganized market where producer countries will strive to maximize their profits as much as they can by increasing production. In this situation, the market will be oversupplied and the oil prices will be forced to drop. By extrapolating this picture (oversupply, low prices) over the foreseen period, we can expect that world oil reserves will be consumed before the anticipated time. In conclusion, the effects of this diversity have to be taken into consideration when projecting the future of oil market and particularly when discussing the domination of OPEC in the next two decades.

The International Energy Agency says that there are 2.3 trillion barrels in ultimate remaining recoverable reserves, and if unconventional resources such as tar sands and shale are included, the number may well be greater than 4 trillion barrels (IEA, *World Energy Outlook 1998*). Therefore, all the indices show that the future of oil in the next two decades is very promising. Oil will remain the world's single most important source for energy in the foreseeable future, and the key constraint on the oil demand and

supply to 2020 will depend upon the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

International crude oil markets have become increasingly global and transparent, where transportation cost is an important factor in determining the profits. Sellers will be more interested in selling their oil to the closest market in order to maximize profits. According to the U.S. Department of Energy (IEO 99), a large increase in demand is expected to come from the developing countries with about half of this increase coming from developing countries in Asia. Virtually all the increase in demand is expected to be met by the Persian Gulf producers. Increased oil production in Venezuela, Colombia, Canada, and Brazil has begun to replace some of the Persian Gulf oil's share in the U.S. market. The share of Gulf producers will be even more threatened when growing oil imports from the Atlantic basin (the North Sea and West Africa) are added in. Thus, in the coming decade, the United States will increasingly rely on oil from within western hemisphere and the Atlantic basin. It is East Asia's dependence on Middle Eastern oil that is rising substantially, not America's (OECD 1999, *Energy: the Next Fifty Years).*

Oil supply in the Middle East is expected to dramatically increase when United States - led sanctions against Iran, Iraq, and Libya are lifted. Iraq, with 112 billion barrels in proven reserves, has been held back from tapping them by U.N. sanctions since it invaded Kuwait in the summer of 1990. If sanctions are eased, one can expect a significant increase in production in the short term. And Iraq will not be the only country pumping more in the oil-rich Gulf. Iran and Kuwait are also working to reopen their oil sectors to foreign investors, hoping to boost their capacity to pump out oil. All of these factors can drive the petroleum market to oversupply, "for the oil market that [in case the

U.N.' s sanctions are lifted] would just mean a period where will be a glut in oil supply and should be a very favorable price market for the world." (Mr. Butler)

Low oil prices in the case of an oversupplied market could mean instability in the Persian Gulf especially knowing that all OPEC members are developing countries, and they are heavily dependent on oil revenues. The longer oil prices drop, the more daunting the economic, social, and political challenges that the Gulf countries will face. Social instability can already be seen in some OPEC countries such as Algeria, Libya, as well as Saudi Arabia and Kuwait after the Gulf War, and a series of crises may erupt as a generation of aging leaders passes. Populations in the region are increasing at a rate of 4 percent or more per year – a pattern that foreshadows the worsening demographic bulges caused by large populations under the age of 25 throughout the Gulf. Already, half of the Gulf's inhabitants are under 15 years old, warning of daunting problems in education and employment as well as increased strains on local infrastructure and resources such as food, water, health, and electric power. Per capita incomes plummeted; in Saudi Arabia, for example, real per capita GDP fell from $11,450 in 1984 to $5,643 a sixteen years later. Since 1982, Saudi Arabia has gone from $140 billion in surplus revenues to run up a national debt of almost $130 billion (*http://middleeastdirectry.com/cs_saudihtm*, Feb.28, 2000).

As the Gulf economies shrink, jobs are becoming an increasingly critical problem. According to recent statistics, about 27-35 percent of males and 95 percent of females are unemployed in Saudi Arabia (*http://middleeastdirectry.com/cs_saudihtm*, Feb.28, 2000).

If employment opportunities remain unchanged, in the near future the government might face difficulties in coping with this expansion, which can lead to a major instability in the country.

The case of low oil prices is expected in the intermediate future because of the factors we discussed in the previous paragraph. In the long-term, prices are projected to increase steadily due to the expected increase in demand (1.9 percent), causing the oil requirement to reach 110 million barrels per day (IEA 98). Most analysis believe that OPEC producers will meet this increase. The question that can be asked is whether OPEC will pursue an increase production policy, or will they prefer instead to see oil prices escalate as demand increases.

To meet the increasing demand, OPEC has to assure a reasonable income to the producing countries in order to implement strategies of production capacity expansion. The case of low oil prices will not provide petroleum industry with enough funds to make the necessary investment to meet the future needed supply. If they do not invest enough money, or do not do it in advance, then the world could face a shortage of oil supplies and downward spiral in the global economy. On the other hand, if prices get too high that will stifle the demand and encourage consumers to diversify and reduce energy consumption. The case of high prices can also encourage non-OPEC suppliers to expand their production, since the high price environment will assure enough revenues to cover production costs and bring reasonable profits.

Taking into consideration the heavy dependence of OPEC countries on oil revenues, we believe that OPEC strategy will be based on intensive investments in production and reduction in operation costs in order to provide a steady supply within an

optimal price range (This assessment is based on the business as usual case where there is no place to any disruption due to environmental or political instabilities).

The political future is one of the most uncertain and speculative assessments that could shape the overall picture of the global energy market. It is very obvious that the Gulf War revealed the dependence of United States on important oil regions and its ability to defend those places under any external threat. In the case of internal instability, this is absolutely not true. The case of Iran revolution in 1970's is a striking example of how difficult it is to cope with internal tremors. At present, Algeria still suffers from opposition movements that threaten people's lives across the country. In the Middle East, the Arab-Israel peace process is stalled; furthermore, around 56 percent of the inhabitants of Palestine believe that military actions against Israel are necessary (Jordan Times, March 11). In the case of Iraq; U.N. sanctions are holding the country from developing the economic infrastructures necessary for the production expansion that all OPEC producers require in order to meet the growing demand for petroleum.

In the long term, as the supply of oil lessens and becomes more concentrated in the Middle East, the probability of price disruption and oil shocks could well rise. However, to overcome this situation, an improvement in the local political conditions will be very essential along with increased co-operation among producer countries and all other energy players.

Looking at USGS estimates of the world oil reserves (Figure 16 & Table 7), along with the increasing rate of oil demand and combined with the expected energy intensity improvements, we believe that oil will still provide important quantities of energy beyond 2020, and decline more or less rapidly afterwards depending on competitiveness of other

energy resources. In the longer-term, the technology along with the environmental issues is expected to be the key factor in shaping the picture of the energy market. However, enough funds have to be provided to invest in new technologies to fill the gap when the last drop of oil is consumed. The increase of greenhouse gases is also a very important concern over the longer run that will make the investment in new technologies that respect the environmental targets very essential.

Summary:

In this project we carried out a study of the world energy outlook in the next two decades. We based our analysis and discussion on the forecasts projected by the International Energy Outlook, U.S. Department of Energy, and some other private and governmental agencies. First, we reported the recent forecasts projected by the agencies mentioned above with a quantitative comparison in order to illustrate the different point of views that experts have toward the future of the global energy market. Second, we conducted a detailed study of the petroleum market including demand, supply, oil prices, reserves, and resources. In order to support our discussion, we carried out a comprehensive study of the Organization of Petroleum Exporting Countries as an important player in the energy market. The discussion presented the history of OPEC, its status in recent years, as well as its role in shaping the future of the energy market. Finally, we concluded this paper by discussing the significance of the parameters that we think would shape the outlook of the global energy market. In summary, this study has showed that the global energy market and particularly the petroleum is very volatile, and any forecast of the energy outlook in the long-term will be only a tentative assessment of

what could happen in the long-run considering the business as usual case. We also concluded that resources are not a key uncertainty on the world oil demand to 2020. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand.

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