Notebook

Notebook provides data not easily found elsewhere, background descriptions of important aspects of the energy system and reports on new developments. Contribution are invited.

Oil In The Persian Gulf: Prospects For The New Millennium

Dr. Gawdat Bahgat

For several decades oil has been the main source of energy worldwide. Since the mid 1970s, oil supplies from the Persian Gulf have been in competition with other sources. This paper argues that at the beginning of the new millennium the Persian Gulf states will assert their dominant role in the world oil market. The study analyzes the current and potential suppliers such as the North Sea and the Caspian Sea Basin. The growing demand in Asia, particularly in China, is discussed. Finally, the conclusion highlights the security dilemma of oil supplies from the Persian Gulf.

Depuis des décennies, le pétrole est la source principale d'énergie dans le monde. A partir du milieu des années 70, l'approvisionnement en pétrole provenant du Golfe persique est en concurrence avec d'autres sources d'approvisionnement. Cet article soutient qu'en ce début du millénaire, les États du Golfe persique affirmeront leur prépondérance sur le marché mondial. L'étude analyse les fournisseurs actuels et futurs, entre autres ceux provenant de la mer du Nord et du bassin de la mer Caspienne. On discute de la demande croissante provenant de l'Asie, particulièrement de la Chine. En conclusion, nous attirons l'attention sur les problèmes de sécurité concernant l'approvisionnement en provenance du Golfe persique.

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Introduction

Over the next several years, world demand for energy will reach unprecedented level. This growing need will be met primarily by oil, natural gas, and coal. The first is expected to remain, as it has been for the last several decades, the dominant energy source. According to the International Energy Agency (IEA) world oil demand is projected to increase from around 70 million barrel per day in 1995 to between 92 to 97 million barrel per day in 2010[1]. This high demand means that at least for the near future, oil will maintain its share of world energy consumption at around 40 percent[2] and consequently will contain its strategic significance as the single most important primary energy source.

In the last two decades, the oil industry has witnessed a tremendous expansion in production all over the world particularly in Latin America and Europe. However, these efforts to diversify oil resources have not changed the consensus among many experts in the industry that the Persian Gulf and the Caspian Basin are the most promising regions to meet the worldwide growing demand for energy. For reasons which will be discussed shortly, the former still is the most important source now and in the near future. Accordingly, the world's dependence on oil supplies from the Persian Gulf is projected to deepen even further in the first decade of the new millennium. This growing dependence means that the world will become more vulnerable to disruption of supplies from the region. Historically, these disruptions had occurred in response to domestic and regional upheavals and caused substantial interruption of oil supplies in particular and of the world economy in general.

This study will examine both the supply and demand sides of the world oil industry. It will analyze the changes in the global oil consumption and the variation from one region to another. In addition, the competition between different suppliers will be discussed. The main conclusion of this paper is that in spite of genuine efforts to diversify oil resources, the Persian Gulf will increase its share in world production and will solidify the emerging and growing dependence of Asia, particularly China, on oil supplies from the region. This projection will have significant political and security implications.

2. Historical Background: Discovery, and Ownership

The foundation of the oil industry in the Persian Gulf dates back to 1901 when the government in Tehran granted William D'Arcy, an Australian financier, a concession. In 1908 oil was discovered at Masjid-i Sulaiman in Southwest Iran. Three years later, the operations were taken over by the Anglo-Persian Oil Company which was re-named the Anglo-Iranian Oil Company in 1935 and the British Petroleum in 1954. Iraq was the second Gulf state where oil was discovered in commercial quantities by the Khanaqin Oil Company, a subsidiary of the Anglo-Persian Oil Company in 1923. In 1932 oil was found in Bahrain and in the following years major concessions were given and discoveries were made in the rest of the region.[3] During most of the first half of the twentieth century oil facilities in Iran were rapidly expanded. Meanwhile, the utilization of oil resources in the Arab side of the Gulf was postponed until the end of the Second World War.

Two developments dominated the oil industry in the Gulf during the 1950s and the 1960s. First, the industrialized world grew more dependent on cheap and steady oil supplies from the Gulf. This dependence was fueled by the launching of the European Recovery Program, known as the Marshall Plan. In this context, the uninterrupted oil flow at a low price from the Gulf was necessary to ensure the economic recovery of the West.[4] Second, partly in response to the increased Western presence and interest in the region, there was an awakened Iranian and Arab nationalism which was translated into several attempts to reduce the influence of the international oil companies and give more power to the indigenous populations and the local governments. Thus, intense negotiations endured for almost three decades following the end of the Second World War. On one side, the Gulf states tried to take control of their major source of revenue and on the other side, the international oil

Table I
Oil Prices (1972-96) US dollars per barrel

Year	$	Year	$	Year	$
1972	01.90	1981	34.32	1990	20.50
1973	02.83	1982	31.80	1991	16.56
1974	10.41	1983	28.78	1992	17.21
1975	10.70	1984	28.07	1993	14.90
1976	11.63	1985	27.53	1994	14.76
1977	12.38	1986	12.97	1995	16.09
1978	13.03	1987	16.92	1996	18.56
1979	29.75	1988	13.22		
1980	35.69	1989	15.69		

Source: The British Petroleum, BP Statistical Review of World Energy 1997, London: The British Petroleum, 1997, p.14.

companies[5] were reluctant to give up or share their power. Important milestones were achieved during these and other negotiations such as the 50-50 arrangement by which companies agreed to pay the local governments 50 percent of profits[6] and Tehran Agreement of 1971 under which companies agreed to a price revision.[7] In 1960 the Organization of Petroleum Exporting Countries (OPEC) was created to facilitate cooperation between oil states in their confrontation with the companies.[8] Finally, in the 1970s most of the companies assets were taken over by the local governments. This significant step was facilitated by the dramatic change in oil prices in the aftermath of the Arab-Israeli war of 1973.

3. Volatility of Oil Prices

As has been mentioned above, oil was sold for a very low price for most of the 1950s and 1960s which contributed substantially to a strong economic recovery and growth in the industrialized world. However, the period from 1973 until 1991 had witnessed an unprecedented level of volatility in oil prices as the following table illustrates.

Table 1 shows four turning points, known as oil shocks, which together demonstrate that oil prices reflect both market forces and policy actions. In other words, oil prices can be seen as the outcome of the interaction between supply and demand and as a reflection of political developments within the Gulf region. The first oil shock took place when Arab oil producing countries decided to impose restraints on oil production and a total ban on the export of oil to certain countries in response to their stand in the Arab-Israeli war of 1973. The second spike resulted from the political turmoil which accompanied the revolution in Iran and was escalated by the war with Iraq. These developments led to a huge drop in Iranian oil production from 5.24 million in 1978 to 1.38 million barrels per day in 1981.[9] The third jump in prices came in 1990 when Iraq invaded Kuwait and the production of the two countries was taken off from the international market.

It is important to point out that the third rise (1990/91) lasted a much shorter time than the previous two. This can be explained at least by two developments. On one side, it seems that industrialized countries have learned how to handle oil shocks from the experiences of the 1970s. On the other side, other producers, particularly Saudi Arabia, increased their production to make up for the Iraqi (and temporarily the Kuwaiti) oil. The Saudi production jumped from 5.06 million in 1989 to 8.33 million barrels per day in 1992.[10] It is to be remembered that the kingdom had asserted its leading role in determining prices in the mid 1980s. The 1986 price plunge occurred when Saudi Arabia shifted from a policy of holding its production down in the interest of price stability, what is known as "swing producer," to one of exporting more of its low-cost oil in order to gain market share.

This huge Saudi share of world oil production particularly since the Gulf war has assured Riyadh the driver seat in drawing the policy of oil prices.[11] For most of the 1970s and 1980s prices reflected an intense competition between two strategies within the producer countries. One group of countries led by Saudi Arabia favored maintaining stable or relatively low prices, and keeping output at the levels required to sustain these prices. These states were characterized by small populations, large reserves, and large capital surpluses. The main goal for this policy was to reduce incentives for consumer countries to switch to other sources of energy or to seek oil from other producers. A contrasting stand was adopted by countries (such as Iran and Iraq) with large populations and extensive development programs. In general they favored high prices to implement their ambitious development plans.[12] These two contradictory strategies created a split in oil prices adopted by OPEC in the second half of the 1970s. Another demonstration of the clash between these two approaches occurred in 1990 when Baghdad accused Kuwait of overproduction and driving prices down. This accusation, among other things, led to the Iraqi invasion of Kuwait.

In the aftermath of the Gulf war oil prices have been stabilized at a moderate rate. In real terms, inflation adjusted, the prices at the beginning of 1998 are near those of the early 1970s. Absent a politically induced supply disruption, prices are likely to remain at the same level for the next several years. No significant escalation is expected. Indeed, if the United Nations sanctions against Iraq were to ease, the increase in oil supply can drive prices down. The International Energy Agency predicts that the price of one barrel of oil will fluctuate between $17 and $21 until the year 2010.[13] Furthermore, given the high level of integration of interests between the Gulf producers and the international market, it can be argued that more economic considerations (i.e., supply and demand) and less political developments are likely to influence oil prices in the foreseeable future.

At the end of the millennium, oil still retains significant advantages over other forms of energy particularly in regard to the pre-supply infrastructure investment and the ease of shipping it from the fields to the markets. In addition, oil still is the most convenient fuel for transportation. Not surprisingly, world oil consumption is projected to increase over the next several years and will vary from one region to another as the following table demonstrates.

Table II
World Oil Consumption By Region 1990-2015
Million Barrels per Day

Region/Country	1995	2015	Average Annual Percent Growth
United States	17.7	22.1	1.1
Western Europe	13.9	15.4	0.5
Japan	5.7	7.8	1.5
Industrialized	42.2	52.3	1.1
Asia	11.1	24.9	4.1
China	3.3	8.6	4.9
India	1.6	3.3	3.8
Africa	2.3	4.4	3.2
Developing	21.4	42.7	3.5
World	69.4	104.6	2.1

Source: Energy Information Administration, International Energy Outlook 1997, Washington DC: United States Government Printing Office, 1997, p.118.

4. More Demand-Where?

As the figures show, there is big gap in oil consumption between the industrialized countries and the developing world on one side, a variation in current and projected consumption within each group on the other side. Two developments can explain these differences. First, economic growth, oil demand increases as economies grow. Affluent nations and people consume more oil. The expected high growth rate in Asia, particularly in China, can be seen as a main reason for closing the gap between developed and developing nations. Second, since the early 1970s the economic expansion in the industrialized countries has tended to be more "environment friendly." In other words, a growing attention has been given to the level of energy intensity (the ratio of total energy consumption to gross domestic product) in most developed countries. Consequently, energy efficiency has improved 1-3 percent per year over the last two decades.[14] Given this energy conservatism, the share of the world's oil consumption in the Organization for Economic Cooperation and Development (OECD) states will decline from its current level of 60 percent to 50 percent by 2015. This change will be in favor of the developing countries.

The highest rise of world oil consumption is projected to be in Asia.[15] Several factors contribute to this projection including the huge population, high and sustained long-term economic growth, less concern about energy efficiency, limited alternatives to oil, and growing urbanization and demand for transportation. Within Asia, China is expected to have the highest growth rate of oil consumption. Beijing became a new oil importer in 1994 and its needs are projected to soar in order to sustain its spectacular economic growth.[16] This soaring Asian demand for oil has been increasingly met by the Persian Gulf producers. This development will have significant economic and strategic implications.

5. More Suppliers-Who?

In order to meet the rising worldwide demand for oil, more efforts have been invested in exploration and production. Thus, the global oil market since the 1990s, has many more players than it had two decades ago. Significant discoveries had been made in Africa (Egypt, Angola, and Congo), in South and Central America (Venezuela, Brazil, and Colombia), in Mexico, and in many other areas. However, two regions pose serious challenge to oil supplies from the Persian Gulf. These are the North Sea and the Caspian Sea Basin.

Over the past several years, the Persian Gulf states have been engaged in a strong competition over global market share with other producers. In 1976, the Gulf's share of world oil supply was 35.7 percent. Two decades later, 1996, it declined to 25.9 percent.[17] In the 1990s, most of the production outside the Gulf has come from the North Sea. According to the International Energy Agency, North Sea oil supply expansion accounted for almost all the supply increase in the Organization for Economic Cooperation and Development (OECD) and over three quarters of the non-OPEC supply increase outside of the former Soviet Union in the period 1992 to 1995.[18] Three developments have contributed to this expansion. First, political instability in the Persian Gulf region has incited many consumers to diversify their oil resources. Second, the more developed financial market and more secure investment environment have enabled the OECD states to provide investors with attractive fiscal terms. Thus, approximately three quarters of total worldwide oil and gas investment are spent in the high-cost OECD countries which have barely 6 percent of global reserves.[19] Third, the increasingly widespread use of three-dimensional seismic imaging, horizontal drilling, and subsea well completion technologies has helped to revive production from mature oil provinces and to reduce development and production costs from new provinces.[20] Given these three elements (political instability in the Gulf, attractive fiscal terms in the OECD states, and improved technology) the market share of the North Sea has grown in the last decade. Paradoxically, this high level of productivity in conjunction with poor reserves will lead to the depletion of oil fields in the North Sea in the not very long term.

The second important challenge to oil supplies from the Gulf comes from the Caspian Sea. Unlike the North Sea, the former Soviet republics, particularly Kazakhstan, Azerbaijan, and Turkmenistan, have shown signs of very promising reserves. The end of the Cold War era has opened the door for a global interest in the oil and natural gas deposits in the region. However, the full utilization of this wealth faces a number of legal, political, and technical restraints. First, there is no consensus on the ownership of oil fields. Iran and Russia claim that the Caspian Sea is really an inland lake whose resources should be exploited and administered jointly by all riparian states.[21] Second, it still is unknown how much oil these countries hold. For example, at the end of 1995 oil reserves in Azerbaijan were estimated at 1.2 million barrels per day.[22] A year later, 1996, they were reported to be 7 million barrels per day. Third, to a great extent the challenge in the Caspian Sea is less in pumping the oil out of the ground and more in getting it into the international market (i.e., transportation). The path to world markets is blocked in virtually every direction by separatist activities and civil wars (Chechnya, Abkhazia, and Nagorno-Karabakh) and even by the United States policy of containing Iran. In addition to winning concessions from the local governments, oil companies have to negotiate safe routes with third parties. The fourth problem is the lack of indigenous commercial, legal, and financial traditions and infrastructures. One of the most frustrating experiences for Western companies is the absence of Western contractual practices.[23]

Given all these obstacles, there is a serious doubt whether energy deposits in the Caspian Basin can meet the growing world demand for oil in a timely fashion. This conclusion highlights the great significance of the Persian Gulf as the main source of oil now and in the foreseeable future.

6. Gulf Oil: Reserves and Production Capabilities

The previous discussion shows that a great deal of world oil demand has been met by sources from outside the Persian Gulf over the last two decades. However, in the long term, the Gulf region is projected to re-gain and expand its share of world oil supply as the following table shows:

Table III
The Persian Gulf States' Share of World Oil Production (1970-2015)

Year	%
1970	27.6
1975	34.0
1980	28.9
1985	17.4
1990	24.3
1995	25.9
2000	29.0
2005	33.4
2010	37.2
2015	41.5

Source: Energy Information Administration, International Energy Outlook, Washington DC: United States Government Printing Office, 1997, p.161. And, Energy Information Administration, International Petroleum Statistics Report, Washington DC: United States Government Printing Office, August 1997, p.43.

Three factors explain the growing share of Gulf oil in world production. First, the great majority of Gulf oil fields are located along effective and well developed transport routes. The Gulf region lies close to the expanding markets of both Asia and Europe which provides an excellent market opportunities. Unlike the Caspian Basin, most oil shipments from the Gulf can reach the international market without passing by third parties. Second, because of the size of oil fields in the Gulf and their geological formation (where large volumes of crude oil are pressured by a layer of natural gas), the Gulf oil is extremely cheap to produce.[24] It is estimated that the cost to produce a barrel of oil in the Persian Gulf ranges between $0.99 and $1.49 which is much lower than the cost of production in the rest of the world.[25] Third, approximately two-thirds of the world's proven oil reserves are in the Persian Gulf.[26] New explorations in the last three decades have increased the Gulf's share of world oil reserves. At the end of 1976, the Gulf's share was 53.3 percent, in 1986 it was 56.3 percent, and by 1996 it reached 64.6 percent.[27] Another way to appreciate this advantage is comparing the reserves-to-production (R/P) ratio.[28] The difference between the Persian Gulf states and most of the rest of the world in terms of the (R/P) ratios is substantial, which points out to a growing dependence of world oil demand on production from the Persian Gulf. This projection suggests that most of the expansion in world production capacity will take place in the Gulf states.

There is no question that the geological structures of most of the Gulf states would allow them to expand their production capacities. However, the problem is less about these geological potentials and more about capital availability. The low oil prices over the last several years combined with high military expenditures have left limited financial resources to invest in updating and expanding the current production capacities. Furthermore, the fiscal policies adopted by most of the Gulf states during the last three decades created not-very friendly environment for foreign investment. In particular, two Gulf states have suffered the most: Iran and Iraq. The war between them (1980-1988) destroyed many of their production infrastructure facilities and left them with very little, if any, financial resources. In the 1990s, the American containment policy against Iran and the United Nations sanctions against Iraq have made a bad situation even worse. In response, in the closing years of the twentieth century, both Iran and Iraq, as well as other Gulf states, have offered more attractive fiscal terms to attract foreign investment in their oil industries.[29] Given the tremendous advantages the Gulf states enjoy, there are signs that international oil companies will increase their investment in expanding production capacity in the Gulf region.

7. Conclusion: Oil Security at the Dawn of a New Millennium

The foregoing analysis points out a growing global dependence on oil supplies from the Persian Gulf region in the next few years. If history is any guide, a renewed and deeper dependence can pose serious threat to social and economic prosperity worldwide. It is to be remembered that the previous oil shocks had resulted in much more than mere shortage of supplies. They had been associated with an increase in consumer prices, a rise in unemployment rates, and a decline in gross national product.[30] Another disruption of supplies from the Persian Gulf can bring similar results.

In order to prevent such a scenario, the industrialized countries led by the United States created the International Energy Agency in the mid 1970s in order to coordinate their policies and ensure stability in the global economy. These efforts reflect a fundamental understanding that oil security is a global issue which requires international cooperation. Given the growing integration among world economies, it became apparent that any disruption in one region would affect the rest of the world. In other words, it became less relevant who is more dependent on supplies from the Persian Gulf: the United States, Europe, or Asia. Economic turmoil in one area would have a negative impact on all. Thus, the security of oil supplies from the Gulf has become a major international concern.

In line with this understanding, many countries from all over the world participated in the Gulf war. Since the early 1990s the main goal of the Western military presence in the region has been to abort any attempt to threaten oil supplies. For the foreseeable future, there is no reason to doubt the international community's determination to keep playing this role. However, there are growing signs that the Western military presence in the Gulf region has been able to prevent war but not to make peace. The threat of a full-scale war similar to the Iraqi invasion of Kuwait has decline but other challenges to oil supplies have become more serious. These include subversion, intimidation, and domestic instability. Any long term peace has to accommodate both Iran and Iraq in a regional security system and support economic reform and political liberalization in all the Gulf states. At the dawn of a new millennium the Gulf region seems to have a long way to go in order to create such a system. In the coming years, another interruption of oil supplies from the Persian Gulf is not likely to happen but can not be completely ruled out.

End Notes

1. International Energy Agency, World Energy outlook, Paris: International Energy Agency, 1996, p.25.
2. Energy Information Administration, International Energy Outlook, Washington DC: United States Government Printing Office, 1997, p.2.
3. For a detailed discussion of oil discoveries in the Persian Gulf see John Marlowe, The Persian Gulf In The Twentieth Century, New York: Frederick A. Praeger, 1962 particularly chapters 5, 10, and 13.
4. Geoffrey Kemp and Robert E. Harkavy, Strategic Geography and the Changing Middle East, Washington DC: Brookings Institution, 1997, p.49.
5. The following oil companies have dominated oil industry throughout most of this century and are known as the "Seven Sisters": Standard Oil of New Jersey (which changed its name to Exxon in 1972 and markets its products in Europe under the name Esso), the Royal Dutch/Shell group, Texaco, Standard Oil of California (known as Socal and marketed as Chevron), Mobil, Gulf, and British Petroleum. Another important company is Compagnie Francaise des Petroles (CFP-marketing as Total but known as Total-CFP since 1985).
6. Fred Halliday, Arabia Without Sultans, New York: Vintage Books, 1975, p.417
7. Europa Publications, The Middle East and North Africa, London: Staples Printers Rochester Limited, 1996, p.123.

8. For a recent discussion of OPEC see Jahangir Amuzegar, "OPEC's Seventh Life," Middle East Policy, Vol.5, No.3, September 1997, pp.25-40
9. Energy Information Administration, International Petroleum Statistics Report, Washington DC: United States Government Printing Office, 1997, p.38.
10. Ibid, p.38.
11. In the OPEC meeting in Jakarta, Indonesia of November 1997 Saudi Arabia re-confirmed its leading role in the oil industry. In response to Saudi request, OPEC decided to raise its production ceiling by about 10 percent from 25.05 to 27.50 million barrels per day.
12. Abbas Alnasrawi, "Oil Dimensions of the Gulf Crisis," in Ibrahim Ibrahim, (ed), The Gulf Crisis: Background and Consequences, Washington DC: Georgetown University Press, 1992, p.43.
13. International Energy Agency, p.33
14. William F. Martin, Ryukichi Imai, and Helga Steeg, Maintaining Energy Security, New York: The Trilateral Commission, 1996, p.8.
15. For a detailed discussion see Mamdouh G. Salameh, "The geopolitics of oil in the Asia-Pacific region and its strategic implications," OPEC Review, Vol.21, No.2, June 1997, pp.125-131.
16. For an analysis of the Asian and Chinese oil policy see Kent E. Calder, "Asia's Empty Tank," Foreign Affairs, Vol.75, No.2, March/April 1996, pp.55-69.
17. Energy Information Administration, International Petroleum Statistics Report, p.43.
18. International Energy Agnecy, p.29.
19. Paul Tempest, "Oil Supply Prospects: A Confused and Shifting Pattern," Middle East International, No.526, May 10, 1996, p.20.
20. Energy Information Administration, International Energy Outlook, p.23.
21. George Lenczowski, "The Caspian Oil and Gas Basin: A New Source of Wealth?" Middle East Policy, Vol.5, No.1, January 1997, p.112.
22. British Petroleum, BP Statistical Review of World Energy, London: The British Petroleum Institute, 1997, p.4.
23. Rosemarie Forsythe, The Politics of Oil in the Caucasus and Central Asia, Adelphi Paper No.300, New York: Oxford University Press, 1996, p.35.
24. Nagy Eltony, "On the Future Role of Gulf Oil in Meeting World Energy Demand," Energy Studies Review, Vol.8, No.1, 1996, p.58.
25. Energy Information Administration, International Energy Outlook, p.36.
26. Proven reserves are crude oil that is recoverable using present technology at current market prices.
27. The British Petroleum, p.4.
28. The reserves-to-production (R/P) ratio is one of the variables looked at by oil industry analysts to evaluate field development plans.
29. Recently, Iran decided to lift the shareholding ceiling for foreign partners in joint ventures from 49 to 99 percent. See Middle East Economic Digest, "Iran: Work on Petrochemical Projects Speeded Up," Vol.41, No.47, November 21, 1997, p.11.
30. Edward R. Fried and Philip H. Trezise, Oil Security, Washington DC: The Brookings Institution, 1993, p.3.

Electricity Planning with Demand Estimation and Forecasting in Saudi Arabia

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This paper reviews the electric power sector in Saudi Arabia, and emphasizes its supply and demand patterns. The average and peak demands as well as the sectoral demands are estimated to the year 2020. It is found that electricity demand in Saudi Arabia is affected by income and is inelastic with respect to price and income in the short-run but is more elastic in the long run. Estimation and forecasting results point to some policy implications concerning investment, pricing restructuring, and potential for privatization.

Cet article examine le secteur de l'électricité en Arabie Saoudite, et plus particulièrement les modèles d'alimentation et de demande. On évalue la demande moyenne et la demande maximale ainsi que la demande sectorielle jusqu'en 2020. Nous avons observé que la demande en électricité est influencée par le revenu, et qu'elle est rigide à court terme quant au coût et au revenu mais souple à long terme. Les résultats de l'évaluation et des prévisions entraînent des conséquences politiques en matière d'investissement, de reformulation de l'échelle des prix et du potentiel de privatisation.

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Introduction

The electric power industry has become an important sector to the national economies of both developed and developing countries. In Saudi Arabia, electricity received a major boost in the country's ongoing five years economic development plans, which started in 1970. Over that period, the Saudi generating capacities of electricity increased by more than 16 fold, while its demand for electricity increased by more than 20 fold; and it is expected the electricity demand will grow at three times the rate of economic growth. In order to meet such a demand, a generation expansion plan was developed where total generation capacity has to increase by more that 250% in the year 2020 which requires some $63.2 billion of capital investment over the next 20 years.[1] Thus, estimating and forecasting electricity demand is vital for planning and investment purposes as well as for reaching sound pricing and management policies. However, changes in the cost structure of the power sector in Saudi Arabia will affect productivity growth and efficiency of that sector and ultimately will affect any decision of privatization.

This paper will focus on estimating demand for electricity and forecasting the peak electricity demand in 2020. After analyzing the economics of the existing Saudi power utilities, policy implications will be drawn.

There are several studies that have dealt with the analysis of the demand for electricity

[1]Total investment required for the realization of the long-term electrification plan is about $120 billion (Saudi long-term Electrification Plan report, 1996)

especially in the industrialized countries. Taylor, (1975) provides an early survey of these studies. More recently, a number of studies estimated and forecast electricity demand especially in the residential sector (Barnard et al., 1996; Hesing, 1994; Branch, 1993; Kokkelenberg and Mount, 1993). Other attempts have addressed particular aspects of electricity demand such as forecasting the peak load and time-of-use price of electricity demand (Ham et al., 1997 Train and Mehrez, 1994; Engle et al., 1992; Caves et al., 1987; Aigner and Hirschberg, 1985; Housman et al., 1979). Supply reliability and demand side management have been discussed by (Willis and Gerrod, 1997; Orans et al., 1994). However, demand analysis of electricity sectors of developing countries in general and of Saudi Arabia in particular has received scant attention. See, for example, (Shrestha and Bhattarai, 1993, Jannuzzi and Schipper, 1991; Al-Sahlawi, 1990).

In the next section of the paper, the Saudi power sector in terms of supply and demand is discussed. The third section presents the demand model and data. The fourth section provides the empirical results and develops the forecast of peak and average load for residential and industrial demand. Finally conclusions and policy implications are presented.

Electric Power In Saudi Arabia

With the implementation of its subsequent five-year development plans, which started in 1970, Saudi Arabia was able to build a modern and integrated power sector. Since 1975, more than 100 small electricity companies scattered all over the Kingdom have been consolidated into major regional companies. There are four Saudi Consolidated Electricty companies (SCECO); SCECO-East, SCECO-Central, SCECO-West, and SCECO-South. The northern region is currently supplied mainly by the General Electricity Corporation (GEC) which was established by the government in 1976 and is still government owned. However, the plan is to interconnect electricity between the different regions in order to economize on the overall reserve generating capacity and boost efficiency. From 1970 to 1996, electricity generation increased by an average of 14% a year. During the oil boom years of the seventies and early eighties, the growth of electricity generation was substantial, and reached an annual growth rate of more than 35%.

Over the same period, peak load increased by an average of 16% a year (see Figure 1). By 1996, the number of power stations reached 73 with 646 generating units and a capacity of 18,780 MW. These plants are operated either by steam, gas or diesel turbines.

This improvement in the quality and quantity of electricity generated is aimed at meeting the ever increasing demand. It is noted that electricity consumption in Saudi Arabia is represented by electricity sold, jumped to about 90 million MWH in 1996, which is almost 25 times what it had been in 1975. This is in line with the growth in electricity generation, and generally matches the Saudi economic growth. Figure 2 presents the relationship between economic growth, electricity consumption and electricity generation. Between 1975 and 1995, three million customers from all economics sectors, and mainly from residential and industrial sectors, were supplied by electricity. Indeed these two sectors are where demand for electricity increased continuously over the past 20 years, in spite of periods of economic stagnation. In 1996, the sectoral shares in total electricity sold were 47% for the residential, 25% for the industrial, 9% for the commercial, and 17% for the public or governmental sector.

As for the price of electricity in Saudi Arabia, it was relatively low and constant in the past. Since the mid-1980s, electricity prices rose and were subject to a brackets system in order to rationalize consumption. Table 1 shows the developments in the pricing of electricity with respect to different sectors in Saudi Arabia.

Irrespective of these pricing schemes, it is noted that there is no significant effects on restraining the fast growing demand for electricity. This indicates the need for more efficient conservation measures as well as new pricing strategies.

Regarding future prospects, plans call for 100 percent electrification of Saudi Arabia by the year 2020, with target of 69,520 MW for generating capacity to meet a forecast peak load of 59,267 MW.

Table 1: Graded tariff of electricity in Saudi Arabia, 1974-1996.

Year	Sector	Price Halalah/KW	Bracket (KWH)
1974-1984	Industrial	5	For any amount consumed
	Non-Industrial*	7	For any amount consumed
1984-85	Industrial	5	For any amount consumed
	Non-Industrial	7 10 15	1 - 100 1001 - 2000 2001 and above
1985-1992	Industrial	5	For any amount consumed
	Non-Industrial	7 10 15	1 - 3000 3001 - 4000 4001 and above
1992 - date**	Industrial	5	For any amount consumed
	Non-Industrial	5 8 15	1 - 4000 4001 - 6000 6001 and above

Source: Electricity Growth and Development in the Kingdom of Saudi Arabia up to year 1996, Ministry of Industry and Electricity, Riyadh, Saudi Arabia, 1996.

* Non-industrial represents Residential, Commercial and Government.

** Since 1995 a fee of 5 Halalas/KWH was put on any monthly consumption exceeding 2000 KWH.

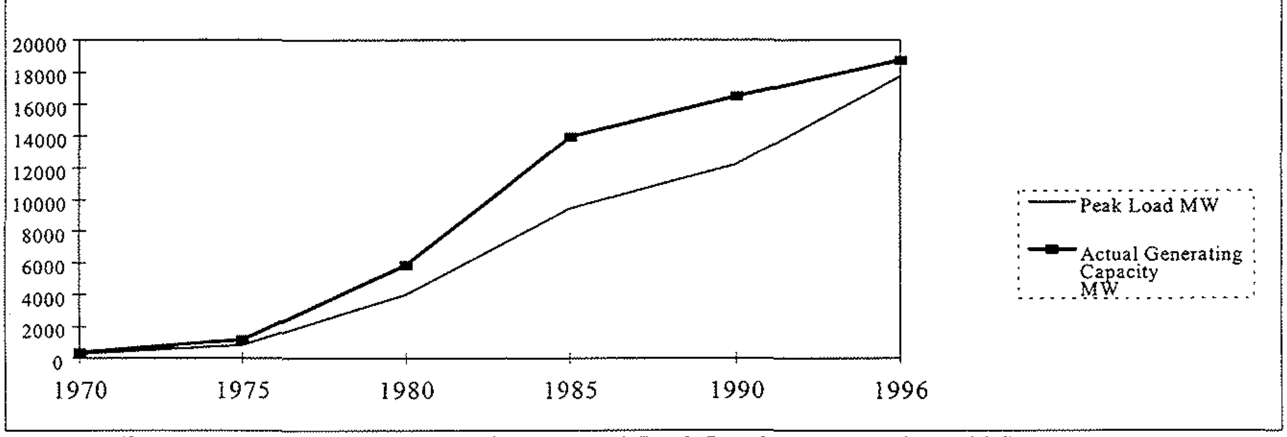

Figure 1 - Actual Generating Capcity and Peak Load in MW, (1970-1996)

Source: Electricity Growth and Development in the Kingdom of Saudi Arabia, Ministry of Industry and Electricity, 1996.

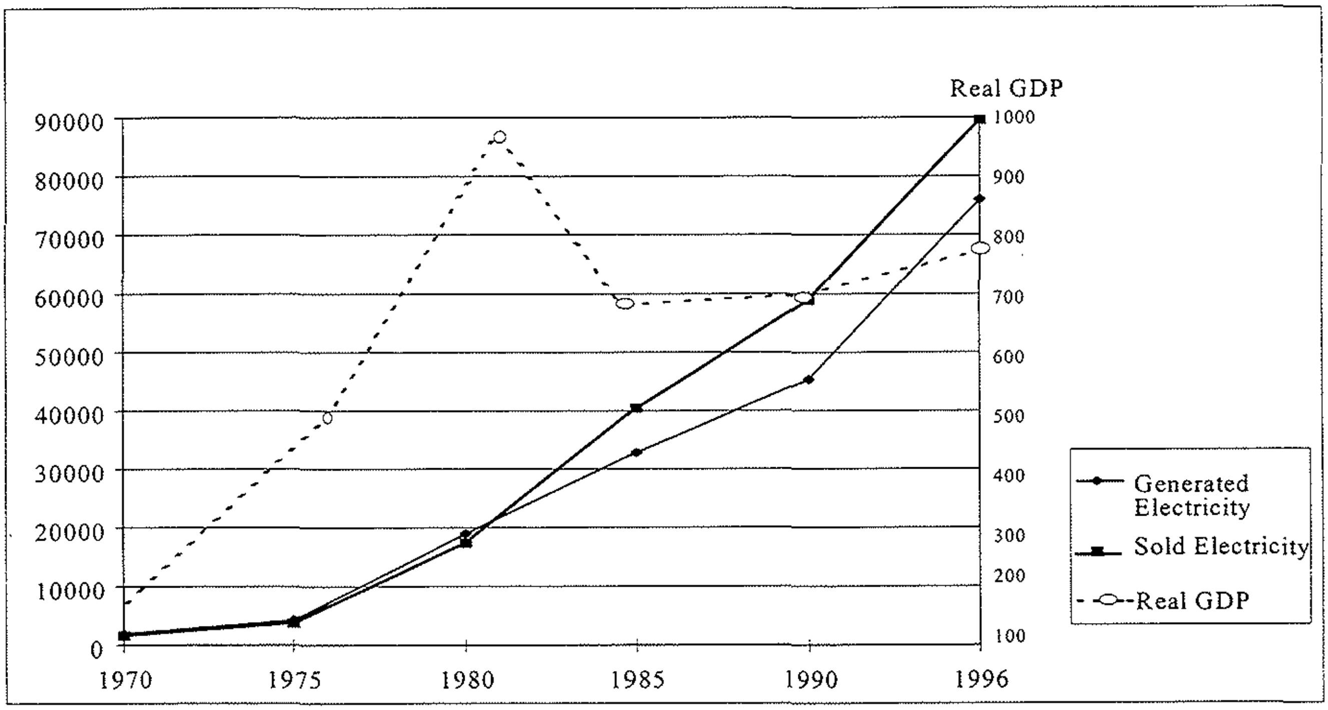

Figure 2 - Generated and Sold Electricity, and Real GDP (1970=100)

Source: Generated and sold electricity is taken from electricity growth and development in the Kingdom of Saudi Arabia, Ministry of Industry and Electricity 1996. RGDP is from Saudi Monetary Agency Annual Report, Ministry of Finance, 1997

The Model and Data

Based on established economic theory and previous studies, the derived demand function can take different forms[2]. In this paper, the demand for electricity is expressed in a log-linear partial adjustment model as:

$$Ln\,Q_{Et} = \beta_0 + \beta_1\,Ln\,(P_{Et}/P_{xt}) + \beta_2\,Ln\,(I_t\,/\,P_{xt}) + \beta_3\,Ln\,Q_{et-1} + \beta_4\,Ln\mathrm{T} \qquad [1]$$

Where β_0 is the intercept, β_1, β_2 ,β_3, and β_4 are he estimated coefficients, the variables are defined below.

Q_{Et} = Average, industrial and residential demands for electricity at period t in MHW

P_{Et} = Price of electricity at period t in Halala/Kwt

I_t = Income; represented by Gross Domestic Product (DGDP) at period t in millions Saudi Riyals

P_{xt} = Price of other consumption goods, represented by Consumer Price Index (CPI) and used as deflator for electricity price and income to obtain their real values at 1970 = 100.

T = A time trend

[2]Mckean and Winger, (1991) lists the functional forms, which include; Linear, Log transform, Semi-log, reverse semi-log reciprocal, Log reciprocal, and Koyck transformation distributed.

Equation 1 presents aggregate demand as well as sectoral demands for electricity; residential and industrial using relevant economic activity as measurement of income where the price of electricity is omitted from the analysis in case of industrial demand since it was constant over the estimated period. β_1 and β_2 are estimates for short-run price and income elasticities respectively, where $\beta_1/(1-\beta_3)$, $\beta_2/(1-\beta_3)$ are the estimates for the long-run elasticities. As far as modeling peak electricity demand is concerned, (Engle et al., 1993) review some references on peak forecasting, and develop models to forecast hourly peak electricity demand. As one of the first attempts, (Al-Sahlawi, 1990) estimates the demand for electricity and forecasts the peak electricity demand of Saudi Arabia in 1995, using the "bootstrapping" technique.

Assuming that average demand for electricity is given as a constant proportion of the peak demand which can be specified in a general log-linear relationship:

$$Log\, Pk_1 = \chi_0 + \chi_1\, Log\, Q_{E_t}$$

where,

Pk_1 = Peak electricity demand at period t in MW

Q_{E_t} = Average electricity demand at period t in MWH

χ_0, χ_1 = Parameters

The above models were estimated econometrically, using OLS method and time-series annual data for the 1975-1996 period. The data on electricity demand and prices are taken from the electricity growth and development reports of the Ministry of Industry and Electricity. The price of electricity that is used in average demand estimation was represented by the weighted average of industrial and non-industrial prices. The data source of CPI and GDP is the Saudi Monetary Agency reports.

Estimation Results and Forecasting

The econometric result of estimating the demand equations are shown in Table 2. The equations fit very well statistically, and all coefficients are significant with the expected signs. The corresponding t-values are given in parentheses under each coefficient. Other relevant statistics are also presented.

Table 2: Estimation Results

Demand	β_0	β_1,	β_2	β_3	β_4	χ_0	χ_1	R^{-2}	DW	F
Average	-0.3 (-0.090)	-0.06 (-1.50)	0.21 (1.85)	0.87 (3.80)	0.01 (1.020)	–	–	0.99	2.12	1503.1
Residential	0.87 (1.29)	-0.10 (-1.70)	0.13 (2.50)	0.80 (4.70)	0.05 (0.99)	--	--	0.99	2.4	2838.0
Industrial	1.73 (1.89)	--	0.08 (1.14)	0.88 (9.61)	0.02 (1.30)	–	–	0.97	2.03	327.40
Peak	–	–	–	–	–	- 7.58 (-32.75)	0.95 (6.6.7)	0.99	1.80	4442.8

The short-run and long-run price and income elasticities are presented in Table 3. It is noted that the demand for electricity in Saudi Arabia is very inelastic with respect to price and income in the short-run and it is more elastic in the long-run. However, these elasticities are comparable to electricity demand estimates done for other countries[3]

Table 3: Price and income elasticities of the demand for electricity in Saudi Arabia

Demand	**Price Elasticity**		**Income Elasticity**	
	SR	**LR**	**SR**	**LR**
Average	-0.06	-0.46	0.21	1.6
Residential	-0.10	-0.50	0.13	0.70
Industrial	–	–	0.08	0.66

Using the parameter estimates, the demand for electricity in Saudi Arabia is forecast to the year 2020. The forecasting is based on two scenarios; first, the base case, where the real price and real gross domestic product change by the moving average. The second scenario assumes 3% per year average growth rate for the real gross domestic product and a moving average real price. Both scenarios assume no major structural or technological changes over the forecast period. The forecast result and the official projection of electricity demand and peak load are shown in table 4. The results of forecasting electricity demand in Saudi Arabia indicate that average demand and peak load will grow by about 5% annually which is close to the official projected growth rates.

Table 4: Electricity demand forecasts to 202 (GWH)*

	Year	**Average**	**Residential**	**Industrial**	**Peak Load**
Scenario 1 (Base case)					
	2000	108,300	57,900	23,640	22,652
	2005	130,027	66,800	24,560	26,959
	2010	150,478	78,240	25,105	30,980
	2015	170,225	87,357	25,500	34,840
	2020	189,700	90,690	25,700	38,622
Scenario II					
	2000	122,900	82,900	23,230	23,566
	2005	157,560	112,300	25,790	30,409
	2010	190,490	147,200	26,930	38,775
	2015	244,400	184,700	27,840	49,156
	2020	312,670	222,450	28,600	62,145
Scenario III					
	2000	147,017	–	–	27,933
	2005	181,052	–	–	34,704
	2010	221,309	–	–	42,643
	2015	264,555	–	–	51,260
	2020	301,828	–	–	59,267

** Peak load is in MW*

*** From Saudi long-term electrification plan, 1996*

Conclusion and Policy Implications

An overview of the electric power sector in Saudi Arabia over the last two decades shows that, electricity generation has increased substantially in order to meet the high growth in demand. However, additional expansion by building a reliable power supply system is needed.

Price and income elasticities of the demand for electricity are important for forecasting and planning in order to reach sound pricing and investments policies. It is found that the average and sectoral demands for electricity are neither price nor income elastic in the short-run; in the long-run, however, the average demand is income elastic. Constant nominal price of electricity especially for the industrial sector did not allow for reliable estimate of price elasticity. Average demand for electricity in Saudi Arabia is forecast to increase by 5% in 2010, and by more than 6% between 2010 and 2020 due mainly to income growth and the cumulative effect of price elasticity. Peak load, on the other hand will increase by almost similar percentage over the same periods. This implies that Saudi Arabia has to continue expanding its power sector and implement economic evaluated demand side management measures to ensure efficiency and rational electricity consumption. For such expansion and development, massive capital investment is needed which can be obtained by total or partial privatization of the electricity sector.

In light of such demand analysis, pricing schemes should be modified and administered in a way to reflect a balance between efficiency and equity, and market conditions.

Acknowledgments

The author would like to thank the King Fahd University of Petroleum and Minerals, Dhahran, and the British Council, Saudi Arabia for funding this study. The author would also like to thank Mr. Shahidul Islam for his statistical assistance. Thanks to Professor Gordon Mackerron, Head of the Energy Program, SPRU, University of Sussex, United Kingdom for his comments and providing research support at Sussex.

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1998 Carbon Dioxide Fact Sheet

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The 1998 issue of the Carbon Dioxide Fact Sheet follows the same format employed in previous years. Energy consumption data for the world and its principal regions and nations is taken from the BP Amoco *Statistical Review of World Energy* and converted to emissions of carbon dioxide using standard factors. This well-accepted source of energy statistics is now mounted on the World Wide Web at

http://www.bpamoco.com/worldenergy/.

The Review is published in the latter part of June following the statistical content year and thus provides a means of estimating emissions of carbon dioxide from the fossil fuels on a consistent basis throughout the world as early as six months after the relevant year-end.

The conversion of one million tonnes of oil equivalent (MTOE), the basic energy unit employed in the Review, was taken here as 41.868 petajoules and the specific factors applied to the three fossil fuels were those used by the International Energy Agency: for oil-19.9 million tonnes of carbon (not the dioxide) per exajoule (MTC/EJ); for natural gas-13.8 MTC/EJ; and for coal-24.1 MTC/EJ, calculated on the basis of the higher heating value. Should it be desired to express emissions in terms of carbon dioxide rather than the carbon convention used in this note, the factor is 3.67. The limitations on the use of energy consumption data for the estimation of carbon dioxide emissions have been noted previously. (Walsh, J.H. (1993) 1992 Carbon Dioxide Fact Sheet, *ESR*, 5:2:131-5). The data in the Table that follows should be considered useful for making relative comparisons among nations and regions, and between this year and last. Absolute values have to await detailed 'bottom-up' assessments.

In 1998, world emissions of carbon dioxide declined marginally by -0.5% while the corresponding primary energy consumption (excluding biomass and non-commercial forms of energy as is the practice in the Review) fell -0.7%, in contrast with the increase of +1.2% in emissions and +1.0% in primary energy consumption reported in 1997. The fossil fuels accounted for 89.9% of the world's energy consumption in 1998. Canadian emissions remained steady and accounted for 2.1% of the world's total. Canada's per capita emissions

Table 1: 1998 Carbon Dioxide Emissions from Selected Countries and Regions

<table>
<tr><th></th><th colspan="4">1997</th><th colspan="4">1998</th><th colspan="3">% Change & C/person</th></tr>
<tr><th>Country/ Region</th><th>Oil MTC/%</th><th>Nat.Gas MTC/%</th><th>Coal MTC/%</th><th>Total MTC/%</th><th>Oil MTC/%</th><th>Nat.Gas MTC/%</th><th>Coal MTC/%</th><th>Total MTC/%</th><th>% In-crease</th><th>% of World</th><th>Tonnes C/Person</th></tr>
<tr><td>World</td><td>2821
45.1%</td><td>1150
18.4%</td><td>2286
36.5%</td><td>6257
100%</td><td>2824
45.3%</td><td>1165
18.7%</td><td>2239
36.0%</td><td>6228
100%</td><td>-0.5%</td><td>100%</td><td>1.05</td></tr>
<tr><td>Canada</td><td>68.4
51.8%</td><td>38.9
29.5%</td><td>24.7
18.7%</td><td>132.0
100%</td><td>69.3
52.5%</td><td>36.6
26.1%</td><td>26.1
19.8%</td><td>132.0
100%</td><td>0.0%</td><td>2.1%</td><td>4.30</td></tr>
<tr><td>U.S.</td><td>706.5
45.0%</td><td>328.3
20.9%</td><td>534.5
34.1%</td><td>1569.3
100%</td><td>710.2
45.3%</td><td>318.5
20.3%</td><td>538.5
34.4%</td><td>1567.2
100%</td><td>-0.1%</td><td>25.2%</td><td>5.80</td></tr>
<tr><td>E.U. (15)</td><td>519.2
56.9%</td><td>174.7
19.2%</td><td>218.4
23.9%</td><td>912.3
100%</td><td>527.9
57.0%</td><td>181.7
19.6%</td><td>216.1
23.4%</td><td>925.7
100%</td><td>+1.5%</td><td>14.9%</td><td>2.48</td></tr>
<tr><td>E. Eur. + FSU</td><td>215.5
26.1%</td><td>302.9
36.7%</td><td>306.6
37.2%</td><td>825.0
100%</td><td>231.6
26.5%</td><td>307.0
38.2%</td><td>284.2
35.3%</td><td>804.8
100%</td><td>-2.4%</td><td>1.4%</td><td>4.72</td></tr>
<tr><td>Australi a</td><td>30.8
35.5%</td><td>10.2
11.7%</td><td>45.8
52.8%</td><td>86.8
100%</td><td>31.2
35.4%</td><td>10.6
12.0%</td><td>46.2
52.6%</td><td>88.0
100%</td><td>+1.3%</td><td>1.4%</td><td>0.49</td></tr>
<tr><td>Brazil</td><td>66.6
82.3%</td><td>3.2
3.9%</td><td>11.2
13.8%</td><td>81.0
100%</td><td>69.3
82.7%</td><td>3.4
4.0%</td><td>11.2
13.3%</td><td>83.9
100%</td><td>+3.6%</td><td>12.7%</td><td>0.64</td></tr>
<tr><td>China</td><td>154.6
18.9%</td><td>10.1
1.2%</td><td>655.1
79.9%</td><td>819.8
100%</td><td>158.6
20.0%</td><td>10.1
1.3%</td><td>620.9
78.7%</td><td>789.6
100%</td><td>-3.7%</td><td>12.7%</td><td>0.64</td></tr>
<tr><td>France</td><td>76.4
70.7%</td><td>18.0
16.7%</td><td>13.6
12.6%</td><td>108.0
100%</td><td>78.7
69.4%</td><td>19.5
17.2%</td><td>15.2
13.4%</td><td>113.4
100%</td><td>+5.0%</td><td>1.8%</td><td>1.93</td></tr>
<tr><td>India</td><td>69.4
29.6%</td><td>11.0
4.7%</td><td>154.1
65.7%</td><td>234.5
100%</td><td>71.7
30.0%</td><td>12.1
5.1%</td><td>155.0
64.9%</td><td>238.8
100%</td><td>+1.8%</td><td>3.8%</td><td>0.24</td></tr>
<tr><td>Japan</td><td>221.9
64.1%</td><td>33.9
9.8%</td><td>90.6
26.1%</td><td>346.4
100%</td><td>212.5
62.9%</td><td>36.1
10.7%</td><td>89.2
26.4%</td><td>337.8
100%</td><td>-2.5%</td><td>5.4%</td><td>2.68</td></tr>
<tr><td>Rest-of -World</td><td>768.5
61.4%</td><td>237.0
19.0%</td><td>245.2
19.6%</td><td>1250.7
100%</td><td>759.5
60.3%</td><td>249.1
19.7%</td><td>251.8
20.0%</td><td>1260.4
100%</td><td>+0.8%</td><td>20.2%</td><td>0.55</td></tr>
</table>

of 4.30 tonnes C/person/year were narrowly exceeded by Australia (4.72) but both countries' per capita emissions were less than those from the US, which were valued at 5.80. Emissions continued to decline in Eastern Europe (a category here that includes all the former members of the old Soviet Union) at -2.4%. The 15 nations of the European Union experienced an increase +1.5% in emissions in 1998 in comparison with a decrease of -1.0% the previous year.

Though a member of the EU, France was listed separately because of the importance of nuclear power in that country (a little over 75% of total generation) which ranks behind only tiny Lithuania. Nuclear energy accounted for 40.1% of France's primary energy supply in 1998 (computed on the equivalent fuel-input basis) though emissions increased +5.0% that year. On the world basis, consumption of nuclear-derived energy increased again following a decline in 1997, reflecting greater generation in the US, South Korea, and some other countries, though there was a decline in Canada. In Canada and France, and for the first time, Eastern Europe (including the countries of the Former Soviet Union), natural gas was a larger source of carbon dioxide emissions than coal. The United States remains the largest contributor to emissions accounting for 25.2% of the world's total in 1998.

The continuing growth in emissions in the large developing countries of Brazil and India was markedly less than last year at +3.6% and +1.8% respectively and emissions actually fell -3.7% in China for the first time. Per capita emissions remain low in all three countries. In the rather heterogeneous category of the Rest-of-World (calculated by deducting all the countries or regions specifically listed in the Table from the world total), emissions rose only +0.8% (a decrease from the +4.1% reported for 1997) but per capita emissions stayed low at 0.55 tonnes C/person/year. Primary energy consumption continued to fall in the Russian Federation. This contraction in energy consumption reflects the continuing economic difficulties being experienced in that region. With a measure of recovery there and in the Asian region which suffered a severe downturn during this period, world emissions of carbon dioxide would be expected to increase more rapidly.

At the Third Conference of the Parties (COP 3) to the United Nations Framework Convention on Climate Change held in Kyoto 1-10 December 1997, Canada committed itself to reduce combined CO_2, CH_4 and N_2O emissions by 6% below 1990 levels and combined HFC, PFC and SF_6 emissions by 6% below 1995 levels between 2008 and 2012. Because of economic and population growth expected in the intervening period, Canada needs, in effect, to reduce its emissions some 20-25% below what they would be otherwise in 2010. The Climate Change Secretariat, established in late 1997 to deal with this problem, created 16 Issue Tables in mid-1998 whose deliberations have resulted in 21 foundation papers (17 available on the Web to date at http://www.nccp.ca/). A National Implementation Strategy is being formulated for consideration by federal and provincial ministers at the end of 1999. In the meantime, the Climate Change Action Fund, funded with $150 million over three years, has announced 38 projects in this field by June of 1999 with another 100 pending.

Further information on world emissions of greenhouse gases may be obtained from the Carbon Dioxide Information Analysis Center of Oak Ridge National Laboratory which may be reached on the Web at http://cdiac.esd.ornl.gov/.