ARAB ENERGY: PROSPECTS TO 2000

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FOREWORD

"World oil production is likely to level off—perhaps as early as 1985—and alternative fuels will have to meet growing energy demand."[1]

"There is no dearth of petroleum and natural gas resources remaining in the earth. As a matter of fact, there is no foreseen shortage of available supplies by present technology until well into the next century."[2]

The statements quoted above are the conclusions of two of the most authoritative reports published in recent years on the future of world oil and energy. The first report was the result of the work of some seventy-five experts over two and a half years. The second emerged from an international conference grouping ninety specialists. Yet, their findings do not seem to coincide.

This is but one of many indications on how controversial the oil issue has become ever since the dramatic warnings of the Club of Rome in 1972, when the notions of "physical limits" and "the carrying capacity of the planet" were publicly introduced. But it was not until after the oil price increases of 1973–1974 that energy became such a central topic to the world predicament. More than one hundred energy projections have been published since then, releasing an impressive range of diverging forecasts. The reasons behind such differences in results were not only of a technical nature. Very few objective studies were issued.

The United Nations Economic Commission for Western Asia (ECWA), with its extremely limited resources, could not possibly fill this gap. But it could not ignore the issue altogether, in view of its paramount importance to the Western Asia region, which possesses almost half the world's oil reserves and meets about half the world's crude import needs.

A first study on the subject of projections of energy supply and demand was completed at ECWA in 1978. It covered the Arab Middle East (twelve countries) and the period up to 1990.[3] It was primarily undertaken by Dr. Nouhad BAROUDI, who also presented it to the First Arab Energy Conference in March 1979.[4]

The discussions at the First Arab Energy Conference and the important events that took place on the oil scene in 1979 revealed the need for a revision of the projections undertaken one year earlier

[1] *Energy: Global Prospects 1985–2000.* Report of the Workshop on Alternative Energy Strategies (WAES), McGraw-Hill Book Company, USA, 1977 (p. 3).

[2] *The Future Supply of Nature-made Petroleum and Gas.* Main report of a conference jointly organized by the United Nations Institute for Training and Research (UNITAR) and the International Institute for Applied Systems Analysis (IIASA), Pergamon Press, USA, 1977 (p. 1).

[3] *Medium and Long Term Projections of the Demand for and Supply of Energy in the ECWA Region,* Natural Resources, Science and Technology Division (Energy Programme), ECWA. Published by the Arab Fund for Economic and Social Development and the Organization of Arab Petroleum Exporting Countries in *Energy in the Arab World: Proceedings of the First Arab Energy Conference (4–8 March 1979, Abu Dhabi, U.A.E.),* Volume 2, Kuwait, 1980.

[4] Dr. Nouhad BAROUDI is the Officer-in-Charge of ECWA's Natural Resources, Science and Technology Division.

and for their extension to the whole Arab world (twenty-one countries) and to 2000. At the same time, a new approach to the question, particularly as regards the crucial issue of Arab oil policies, appeared to be warranted. The work was completed by the middle of 1980, again by Dr. Nouhad BAROUDI. It is the subject of this book.

M.S. AL-ATTAR
Executive Secretary
ECWA

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General

1. The terms "Arab world," "region," and "area" are used interchangeably to designate the area covered by the following States: Algeria, Bahrain, Democratic Yemen, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Somalia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen.

2. A bracketed number, such as [1], refers to the document of that number in the "Selected Bibliography" list at the end of the book.

3. Tables and figures are designated by a two-digit system. Table 3.2, for example, would be the second table of Chapter 3; Table A8.1 would be the first table of Appendix 8.

4. "Dollars" refers to dollars of the United States of America.

5. The following equivalencies are used:
kilo = thousand = 10^3
mega = million = 10^6
giga = billion = 10^9
tera = trillion = 10^{12}
exa = billion billion = 10^{18}

Acronyms

ALECSO : Arab League Educational, Cultural, and Scientific Organization
CEC : Commission of the European Communities
ECA : United Nations Economic Commission for Africa
ECWA : United Nations Economic Commission for Western Asia
IAEA : International Atomic Energy Agency
IEA : OECD's International Energy Agency
IIASA : International Institute for Applied Systems Analysis
LAJ : Libyan Arab Jamahiriya
MIT : Massachusetts Institute of Technology
OAPEC : Organization of Arab Petroleum Exporting Countries
OECD : Organisation for Economic Cooperation and Development
OPEC : Organization of the Petroleum Exporting Countries
SAR : Syrian Arab Republic
UAE : United Arab Emirates
UNEP : United Nations Environment Programme
UNESCO : United Nations Educational, Scientific and Cultural Organization
UNICEF : United Nations Children's Fund
UNITAR : United Nations Institute for Training and Research
USA : United States of America
USSR : Union of Soviet Socialist Republics
WAES : Workshop on Alternative Energy Strategies

Abbreviations

b : barrels
Bb : billion barrels
Bcf : billion cubic feet
b/cd : barrels per calendar day
b/d : barrels per day
b/sd : barrels per stream day
boe/d : barrels per day of oil equivalent
Bt : billion metric tons

Btoe	:	billion metric tons of oil equivalent
cu.m	:	cubic metres
cf	:	cubic feet
cf/d	:	cubic feet per day
EJ	:	exajoules
GW	:	gigawatts
GWh	:	gigawatt-hours
J	:	joules
kcal	:	kilocalories
km	:	kilometres
km/h	:	kilometres per hour
kW	:	kilowatts
kWh	:	kilowatt-hours
LNG	:	liquefied natural gas
LPG	:	liquefied petroleum gas
Mb	:	million barrels
Mb/cd	:	million barrels per calendar day (Calendar day figures refer to what refiners actually run in a year divided by 365.)
Mb/d	:	million barrels per day
Mb/sd	:	million barrels per stream day (Stream day figures represent the potential a refinery can yield when running at full capacity.)
Mboe/d	:	million barrels per day of oil equivalent
Mcf/d	:	million cubic feet per day
Mt	:	million metric tons
Mtoe	:	million metric tons of oil equivalent
MW	:	megawatts
NGL	:	natural gas liquids
NGN	:	natural gasolene
sq.m	:	square metres
sq.km	:	square kilometres
t	:	metric tons
Tcf	:	trillion cubic feet
TJ	:	terajoules
toe	:	metric tons of oil equivalent
TWh	:	terawatt-hours

ONE
EXECUTIVE SUMMARY

This chapter presents in capsule form the purpose, scope, findings, and conclusions of the main chapters of this study.

METHODOLOGY

The Arab world's energy projections are carried out in this study within the framework of a regional energy balance model, in the consolidated form presented in Table 1.1.

Energy balances are a consistent framework for presenting (by type of fuel: solid fuels, crude oil, petroleum products, natural gas, electricity, and nonconventional sources) the domestic supply, imports and exports, transformation, and consumption of energy—all expressed in a common unit taken here as the metric ton of oil equivalent (toe).[1] The results of the projections, however, are not only presented in million toe (Mtoe) but also in million barrels per day of oil equivalent (Mboe/d) and in exajoules (EJ) for easy reference.[2]

The projections for solid fuels, natural gas, and primary (hydro, nuclear, solar, biomass, geothermal, and wind) and conventional thermal electricity are undertaken on the basis of a critical assessment of programmes and perspectives of each of the twenty-one Arab countries in each of these fields. As for the oil projections (crude oil and petroleum products), they are mainly based on a (hypothetical) clearly spelled out, long-term Arab policy for both crude production and refining.

Emphasis will be put here on this assumed collective Arab policy, on the one hand, and on the quantitative findings of the study, on the other.

OIL POLICY

An Arab Long-term Crude Oil Production Policy

An analysis of the world oil and energy situation since 1974 has highlighted the following points:

1. Most of the oil and energy projections published since the oil price increases of 1973–1974 have ignored the viewpoint of the producers. This is because these studies have mainly originated in the Western world and, hence, have reflected the viewpoint and biases of the consumers. This is also because there has so far been no clearly defined, common producers' viewpoint.

2. The tight oil market which prevailed in 1979 as a result of the Iranian revolution has created a climate of uncertainty about oil prices and supply availabilities that may well continue in the future.

3. There is a clear need for cooperative action at the international level to ensure that future oil demand does not exceed available supplies.

[1] One toe is defined as 10 million kilocalories.

[2] For approximate conversions, divide figures in Mtoe by 50 to get Mboe/d, and by 24 to get EJ.

Table 1.1

Energy Balance Model.

	Solid fuels	Crude Petroleum	Petroleum products	Natural gas	Primary electricity	Electricity	Total
Primary energy production	PSF	PCP	PGL	PNG	PPE		P
Net energy exports (–)	–XSF	–XCP	–XPP	–XNG		–XEL	–X
International bunkers (–)		–	–BNK				–B
Total primary energy requirements	TSF	TCP	TPP	TNG	TPE	TEL	TER
Electricity generation	–ESF	–ECP	–EPP	–ENG	–EPE	ELG	–W
Refineries		–RCP	REF	–RNG		–REL	–R
Gross final consumption	CSF	–	CPP	CNG		CEL	GFC

Notes:

1. The projections cover the period up to 2000 with the following bench-mark years: 1985, 1990, and 2000.
2. Projected magnitudes of the 38 variables in the model are expressed in million toe (Mtoe), with one significant digit after the decimal point in the case of the 1985 estimates, but rounded off to the nearest integer in the case of the 1990 and 2000 estimates.
3. A dash (–) indicates nil quantities or figures below 0.05 Mtoe in 1985 and below 0.5 Mtoe in 1990 and in 2000.
4. A blank means that the corresponding item is not applicable.

Model Variables

The 38 variables of the energy balance model are defined in the order in which they appear in Table 1.1. (reading down the columns).

PSF: Production of solid fuels.
XSF: Net exports of solid fuels.
TSF: Total domestic requirements of solid fuels.
ESF: Solid fuels burnt in thermoelectricity plants.
CSF: Gross final consumption of solid fuels.
PCP: Production of crude petroleum.
XCP: Net exports of crude petroleum.
TCP: Total domestic requirements of crude petroleum.
ECP: Crude petroleum used directly as fuel in thermoelectricity plants.
RCP: Crude petroleum entering refineries.
PGL: Production of natural gas liquids (NGL).
XPP: Net exports of refinery products and NGL.
BNK: Petroleum products used in international bunkering operations.
TPP: Total domestic requirements of petroleum products.
EPP: Petroleum products fueling thermoelectricity plants.
REF: Refinery output.
CPP: Gross final consumption of petroleum products.
PNG: Production of natural gas.
XNG: Net exports of natural gas.
TNG: Total domestic requirements of natural gas.
ENG: Natural gas fueling thermoelectricity plants.
RNG: Refineries' own use of natural gas.
CNG: Gross final consumption of natural gas.
PPE: Production of primary electricity.
TPE. Total domestic requirements of primary electricity.
EPE: Primary electricity fuel input equivalent.
XEL: Net exports of electricity.
TEL: Net trade in electricity.
ELG: Gross electricity generation.
REL: Refineries' own use of electricity.
CEL: Gross final consumption of electricity.
P: Total production of primary energy.
X: Total net energy exports.
B: International bunkers.
TER: Total domestic primary energy requirements.
W: Waste heat (or energy loss) in electricity generation.
R: Refineries' own energy use and losses.
GFC: Gross final consumption.

All three points underline the necessity of a well defined, long-term production strategy for the producers. First, it would be difficult for any serious "Western projection" exercise to ignore a clearly and collectively spelled out producers' viewpoint, which would render the exercise more objective and, hence, more useful in mapping energy futures. Second, a producers' strategy would clearly show the extent of the conservationist production policies in major exporting countries and would, thus, lift the uncertainty now prevailing about future oil supplies. Third, the strategy would provide a basis for a much needed concerted action between producers and consumers in the light of which the latter could initiate the long-term adjustments in their economies necessary to ensure that future oil demand would not exceed available supplies.

The Arab world plays and will continue to play a key role on the international oil scene. Arab countries account for some 60 percent of total world crude oil exports and meet about two-thirds of the net crude import needs of the OECD area. A well defined, clearly spelled out Arab long-term crude oil production policy would, therefore, constitute a factor of prime importance in lifting the uncertainty about future world oil supply availabilities and, hence, assisting the oil importing countries in their efforts to adjust their economies on a durable basis to the future oil and energy situation.

Any sound crude oil production policy for the Arab world has to be based on the area's long range interests and how it perceives those interests with respect to reconciling the objectives of resource conservation and current financial development needs. The prime concern of this developing region, in the face of rapidly growing demand for its depletable oil resources, is that these resources should last as long as it would need them. In more explicit terms, oil should continue to provide the fuel, raw material, and foreign exchange required for a rapid and balanced development and diversification of the Arab economies, and it must continue to provide until it can be replaced by alternatives that would be available (with appropriate technologies) at competitive prices and in sufficient quantities. With the present state of development of alternative energy sources and their prospects as seen today, it is widely recognized that these will not play an important role in the energy balance of the industrialized world before the turn of the century. As to when appropriate new technologies would be available and well established on a sufficiently large scale in the Arab world so as to make substantial contributions to the Arab energy balance, the future is even more uncertain and the lead times much longer. When that time comes, renewable sources such as solar energy, nuclear power, wind energy, biomass conversion, and geothermal energy—together with the plentiful resources of unassociated natural gas that are estimated to exist in a number of Arab countries—would constitute the new oil alternative energy resource base for the Arab world. But even then oil would have to continue to be used as raw material for nonenergy purposes.

In view of the above, one of the prime concerns of an Arab long-term crude oil production policy should be resource conservation. It is assumed here that an aggregate reserves to production (R/P) ratio of 20 to 1 is the minimum that the Arab world as a whole would envisage today for a long period of time into the future. This 20 to 1 lower limit, being an Arab average, would, of course, conceal upward and (especially) downward variations in the R/P ratios of individual countries, depending on their respective contributions to aggregate output. Some of the countries with a ratio below the 20 to 1 average would even be getting close to their "technical limit," beyond which it would be impossible for them to continue to produce without reducing the amount of crude that could be eventually recovered.[3] It is noteworthy that in 1979, for example, the R/P ratio of each of Algeria, Bahrain, Egypt, Morocco, Dubai, and Sharjah was already below 20 to 1.

The chief prerequisite for the formulation of a sound production policy is an accurate assessment

[3] The world average for this "technical" R/P limit is estimated at 10 to 1.

of Arab recoverable oil resources. This includes, for any one year, the level of proved reserves as well as future gross additions to proved reserves. It is essential that such an assessment be undertaken by an independent body, preferably a pan-Arab organization specially established for that purpose. This is because the estimation of proved reserves that has so far been generally undertaken in the Western world may not have been completely objective at times nor sufficiently documented. These factors have resulted in published estimates of Arab proved reserves sometimes ranging widely from one source to another or incurring substantial revisions from one year to another.[4]

The Arab body to be entrusted with this task would, of course, have to have access to all relevant national information in order to effectively fulfil its mandate. It would carry out its estimation work on a recurrent basis, in the sense that the estimates of the level of proved reserves and future gross additions to reserves would remain under constant scrutiny and would undergo continuous updating in the light of newly acquired knowledge. Results would be made public on a regular basis, say every other December, and preferably for the Arab world as a whole.

For the sake of illustration, and in order to highlight some of the problems involved in this task, an independent specialist was commissioned by ECWA to assist the author of this book in the estimation of the level of proved reserves and of future gross additions to reserves. The exercise had to be limited by tight time and budgetary constraints, but it gives a sketchy illustration of what the independent inter-Arab estimation work described above could be.

On the basis of these findings, a hypothetical Arab crude oil production policy model is applied, whereby Arab output would be increasing by 2 percent per annum between 1980 and 1990, by 1 percent between 1990 and 2000, and would be maintained at the same level (reached in 2000) throughout a period extending from the turn of the century to the year when the R/P ratio would reach 20 to 1, beyond which production would be determined as 5 percent (one-twentieth) of reserves. The application of the model, which is carried out year by year up to 2025, indicates that the R/P ratio would reach the 20 to 1 limit in 2009. Accordingly, Arab crude oil production is projected as shown in Table 1.2.

It may be interesting to compare projected output to anticipated sustainable productive capacity in the Arab world. On the basis of the findings of Fransisco Parra,[5] it is estimated that Arab crude oil sustainable productive capacity would increase by 0.3-0.4 Mb/d per annum between 1980 and 1990 and by 0.2-0.3 Mb/d per annum between 1990 and 2000. Thus, future production would compare to capacity as shown in Table 1.3.

A last remark bears upon the distribution of total Arab output among individual producing countries. The analysis has so far dealt with the Arab world as a whole, and the long-term production policy described above has yielded a future Arab crude oil production profile in aggregate. In reality, agreement on an aggregate output target cannot be reached without a broad understanding on individual country contributions to that output. For the Arab production policy to be implemented in an effective and durable manner, it is essential that national interests be safeguarded. For instance, countries with large populations, ambitious development programmes, and/or financial deficits may need to produce near capacity, while others may have conservationist production policies. The target output should, therefore, be apportioned among individual countries with due regard to their national goals and aspirations.

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[4] For example, *Oil and Gas Journal* and *World Oil* estimates of Arab proved reserves at the beginning of 1978 differed by some 45 billion barrels (Bb). *Oil and Gas Journal* revised downwards at the beginning of 1974 its estimate of Arab proved reserves published one year earlier by 45 Bb. (Arab crude production in 1973 amounted to 6.8 Bb.)

[5] *World Producing Capacity of Hydrocarbons,* a paper presented at the Tenth World Petroleum Congress (Bucharest, September 1979) in a Round Table Discussion on "World Demand for and Supply of Oil and Gas."

Table 1.2

Projection of Arab Crude Oil Production, 1980-2010.

	1980	1985	1990	1995	2000	2005	2010
In Mb/d	20.9	23.1	25.5	26.8	28.2	28.2	26.8
In Mtoe	1,061.4	1,172.5	1,295	1,361	1,431	1,431	1,361

OPEC has so far been leaving decisions on production levels to individual member countries, and an OPEC coordinated production programme is not likely to be introduced in the near future. It is worth noting to this effect that the report of the Group of Experts of the OPEC Ministerial Committee on Long-term Strategies, which was to be presented subsequently to an OPEC summit meeting for adoption, concentrated on pricing issues and relations with developing and developed countries rather than on production programming.

This is yet another reason why it is important that the Arabs should succeed in this endeavour. Furthermore, the Arab world represents a much more homogeneous entity than the group of countries forming OPEC. Finally, within a context of common geographical, human, political, and economic motivations and aspirations, Saudi Arabia would probably show more willingness to play the role of swing producer, so as to ensure to the Arab production programme the internal flexibility necessary for its successful implementation.

An Arab Long-Term Refining Policy

This study assumes that, as a matter of policy, future Arab refinery output would comprise the following components:

1. The amount of refined products necessary to meet Arab demand, inclusive of bunkers.

2. An additional percentage of the amount in 1. above, as a result of the surplus in certain products (e.g., heavy distillates) that would inevitably emerge in meeting demand for other products, and also as a result of modest product exports in a few cases.

3. A certain amount of exportable refinery feedstock produced from heavy, sour crude in specialized Arab refineries.

4. A certain amount of products refined on commission in some non-Arab consumption centres.

Justification of this assumption is provided below.

Many plans to build "export" refineries (i.e., large plants producing petroleum distillates essentially for export) have been announced in the Arab world since 1974. In the event that all such plans were to be executed, Arab primary refining capacity would be pushed to over 10 Mb/d by 1985. As it happens, a number of projects have been abandoned or delayed, and an analysis of current programmes implies that a maximum of 5 Mb/d would be added during the 1980s to Arab capacity, which stood at around 3.3 Mb/d by mid-1980 (or about 4 percent of world capacity).

Table 1.3

Future Arab Crude Oil Production Compared to Capacity, 1980-2000 (Mb/d).

	1980	1985	1990	1995	2000
Arab sustainable productive capacity	25.6	27.4	29.2	30.5	31.7
Arab production	20.9	23.1	25.5	26.8	28.2
Excess sustainable capacity	4.7	4.3	3.7	3.7	3.5

A recent ECWA study[6] has challenged the economics of export refineries, arguing that such ventures have the perverse consequence of turning crude oil, which is cheap to transport (in large "dirty" tankers) into products that are expensive to transport (in small "clean" tankers). This is quite apart from the fact that the existing excess capacity of crude carriers, which means that they can be hired at anomalously low freight rates, may well continue in the future, particularly if the amount of crude to be carried ceased to rise as a result of increased refining and conservationist crude production policies in the main exporting countries. Besides, the substantial surplus refining capacity existing in all areas outside the USA and Japan has narrowed refinery margins and led to difficulties in marketing certain products, even at cut prices, and this trend is likely to continue in the future. Moreover, an oil exporting country that built an export refinery might well be able to overcome these problems (and show a profit in the refinery) either by supplying it with cut-price crude or by using "leverage" to force the oil companies to take the products at uneconomic prices as a condition of being guaranteed a certain amount of crude at official prices. In both cases, however, the profitability of the export refinery would be the result of a subsidy, given directly in the former case, but hidden in the latter since "leverage" could have otherwise been used for other more economically useful purposes. Finally, export refineries, as assessed in relation to alternative development projects, are capital-intensive, have a long gestation period, require a large outlay of foreign exchange for establishment, put a strain on the construction industry and on the government machine (which are normally over-stretched in rapidly developing economies due to limited absorptive capacity), generate a relatively small value added, of which an unusually large proportion represents depreciation (which is not part of national income), add little or nothing to the net earnings of foreign exchange that could have been obtained by exporting the crude oil, require a high proportion of skilled and professional workers, and have little in the way of useful linkages with the rest of the economy, either during the construction phase or when the refinery is in operation.

The ECWA study concludes that it is "clearly advantageous for refineries to be built on a scale at least sufficient to keep pace with the expected growth of regional demands for refined products."

In more explicit terms, refineries would be so designed as to primarily meet Arab demands for products but would also generate a surplus for two reasons. First, the output mix cannot be expected to match the consumption mix at all exactly. Thus, there would have to be regular surpluses in certain products to ensure an adequate supply of each separate product. Such surpluses would have to be exported, but they are anticipated to gradually decline in relative terms with the emergence of new, more sophisticated refineries and the reconversion of some existing ones, which would bring the overall output mix more in line with the Arab consumption pattern. Second, patterns of product demand are not the same in all areas of the world, so that some international trade in specific products is needed to bring supply and demand into balance everywhere. This makes it advantageous to have a limited surplus capacity in a central position (e.g., the Gulf) that can supply some products to major consuming areas that are far apart (e.g., Europe and Japan).

On the other hand, a paper presented at the Tenth World Petroleum Congress in September 1979[7] has projected that future oil demand growth in the major consuming areas would be largely for lighter, sweeter products, at a time when supply increases would be predominantly in heavier, sour crude oils, particularly in OPEC countries.[8] Meet-

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[6] *Study on the Economics of Oil Refining in the ECWA Region*, Energy Programme, Natural Resources, Science and Technology Division, ECWA (April 1980).

[7] *Developments in the Economics of Petroleum Refining,* by P.H. Frankel and W.L. Newton (Special Paper No. 6).

[8] In the case of Saudi Arabia, the paper has estimated that the share of Arabian Light in total crude output would decline from 72 percent in 1977 to 50 percent in 1985.

ing these expected changes in product demand patterns and quality specifications presupposes the supply of adequate quantities of suitable crude oils and the requisite refinery upgrading and conversion capacity. One way of solving the problem would be to take the opportunity of the refining developments in producing countries to convert heavy (low-API gravity), sour (high-sulphur) crude oil into lighter (higher-gravity), sweeter (lower-sulphur) "reconstituted" crude for export, making use of the availability of associated flare gas for an energy-intensive hydrocracking process.

There would be definite advantages in performing such conversion operations in Arab oil-producing countries. First, the conversion cost, as estimated by the paper, seems to be well below the current value differential between the corresponding input and output crudes. The producer would, thus, benefit from the "uplift" of this operation, which would be particularly profitable in the Arab world, where heavy crude oils are expected to have an increasing share in the crude output mix and where important quantities of associated gas (to be used as feedstock in the conversion process and also as fuel) are still being flared. Second, this activity would help integrating the growing capacity in Arab countries into the world refining system at a time of worldwide surplus capacity. Third, it would relieve the producer of the problem of marketing finished products. Fourth, the reconstituted crude could still be transported in large crude carriers. And fifth, the output crude could be "tailor-made," possibly seasonally varied, for the marketing needs of refineries in the consuming areas.

The supply of reconstituted crude oil is not a new development. It has taken place in the past but mainly within the integrated channels of the major international oil companies or under long-term contractual arrangements between suppliers and individual refiners. It is not suitable for short-term operations, but it could form the basis for forging long-term relationships between producer and consumer country refineries, giving the former a share in the "uplift" and providing the latter with a durable supply of suitable crude oil.

Finally, Arab producers have recently been making use of the excess capacity in some European refineries to run a certain amount of crude for a fee and sell the finished products on nearby markets. This operation is clearly advantageous because substantial savings are made by transporting crude to consuming areas instead of products refined at home. Moreover, refineries near the markets normally yield a product mix more in line with the consumption pattern than the output mix of producer country refineries, and this helps greatly in marketing the various products. All in all, the activity appears to be quite profitable, provided that surplus capacity near the consuming markets remains available, and this is likely to continue to be the case in all areas outside the USA and Japan.

QUANTITATIVE FINDINGS

Arab Energy Balances, 1985, 1990, and 2000

The results of the projections are presented in Tables 1.4, 1.5, and 1.6 in the form of energy balance sheets.

An illustrative geographical breakdown of the Arab world energy balances for 1985, 1990, and 2000 is also attempted in the study, and tentative results are given for the following countries or groups of countries:

- Algeria
- Egypt
- Libyan Arab Jamahiriya
- Other Arab Africa (Djibouti, Mauritania, Morocco, Somalia, Sudan, and Tunisia)
- Iraq
- Kuwait
- Saudi Arabia
- United Arab Emirates
- Other Arabian Peninsula (Bahrain, Democratic Yemen, Oman, Qatar, and Yemen)
- Other Arab Middle East (Jordan, Lebanon, and Syrian Arab Republic)

Analysis of the Results

The Arab world's total primary energy requirements (TER) are projected to increase between 1977 and 2000 by 8.7 percent per annum on the average, compared to 10.4 percent during 1960-1977. Taking into account the growth rate of Arab gross domestic product (GDP) in both periods (7.0 percent), the GDP elasticity of TER would stand at an average of 1.24 in the projection period, as against 1.44 in 1960-1977. A closer look at the evolution of the elasticity during the period 1960-2000 shows a drop from an average of 1.33 during 1960-1972 to 1.01 in 1973-1977, then an increase

Table 1.4

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	2.4	1,172.5	100.1	151.4	7.2		1,433.6
Net energy exports (–)	1.2	–911.3	–183.3	–63.6		–	–1,157.0
International bunkers (–)	–	–	–28.7				–28.7
Total primary energy requirements	3.6	261.2	–111.9	87.8	7.2	–	247.9
Electricity generation	–0.6	–2.0	–22.9	–21.9	–7.2	15.1	–39.5
Refineries		–259.2	249.7	–5.7		–0.5	–15.7
Gross final consumption	3.0	–	114.9	60.2		14.6	192.7
				1990			
Primary energy production	3	1,295	107	239	16		1,660
Net energy exports (–)	1	–893	–257	–113		–	–1,262
International bunkers (–)	–	–	–33				–33
Total primary energy requirements	4	402	–183	126	16	–	365
Electricity generation	–1	–3	–32	–38	–16	26	–64
Refineries		–399	384	–12		–1	–28
Gross final consumption	3	–	169	76		25	273
				2000			
Primary energy production	4	1,431	138	382	32		1,987
Net energy exports (–)	1	–702	–432	–147		–	–1,280
International bunkers (–)	–	–	–40				–40
Total primary energy requirements	5	729	–334	235	32	–	667
Electricity generation	–1	–4	–45	–92	–32	56	–118
Refineries		–725	694	–28		–2	–61
Gross final consumption	4	–	315	115		54	488

Notes:

1. A dash (–) indicates nil quantities or figures below 0.05 Mtoe in 1985 and below 0.5 Mtoe in 1990 and in 2000.
2. A blank means that the corresponding item is not applicable.

Table 1.5

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (Mboe/d).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.05	23.78	2.03	3.07	0.15		29.08
Net energy exports (−)	0.02	−18.48	−3.72	−1.29		–	−23.47
International bunkers (−)	–	–	−0.58				−0.58
Total primary energy requirements	0.07	5.30	−2.27	1.78	0.15	–	5.03
Electricity generation	−0.01	−0.04	−0.47	−0.44	−0.15	0.31	−0.80
Refineries		−5.26	5.07	−0.12		−0.01	−0.32
Gross final consumption	0.06	–	2.33	1.22		0.30	3.91
				1990			
Primary energy production	0.1	26.3	2.2	4.8	0.3		33.7
Net energy exports (−)	–	−18.1	−5.2	−2.3		–	−25.6
International bunkers (−)	–	–	−0.7				−0.7
Total primary energy requirements	0.1	8.2	−3.7	2.5	0.3	–	7.4
Electricity generation	–	−0.1	−0.7	−0.7	−0.3	0.5	−1.3
Refineries		−8.1	7.8	−0.3		–	−0.6
Gross final consumption	0.1	–	3.4	1.5		0.5	5.5
				2000			
Primary energy production	0.1	29.0	2.8	7.8	0.6		40.3
Net energy exports (−)	–	−14.2	−8.8	−3.0		–	−26.0
International bunkers (−)	–	–	−0.8				−0.8
Total primary energy requirements	0.1	14.8	−6.8	4.8	0.6	–	13.5
Electricity generation	–	−0.1	−0.9	−1.9	−0.6	1.1	−2.4
Refineries		−14.7	14.1	−0.6		–	−1.2
Gross final consumption	0.1	–	6.4	2.3		1.1	9.9

to 1.55 in 1978–1985, and finally a gradual decline in 1986–2000 with an average of 1.05. The reduction in the elasticity during 1973–1977 reflects increased economic activity in the Arab world as a result of higher oil revenues since 1973, which manifested itself more particularly in nonenergy intensive sectors (construction, services, government, etc.).[9] The heavy industrialization projects going on or planned in the major Arab oil countries are in line with the higher elasticity level estimated up to 1985. As for the 1986–2000 period, it would witness a gradually declining ratio comparable, on average, to the elasticity that prevailed in the OECD area during 1960–1977.

[9] Arab value added in these sectors increased by more than 69 percent between 1972 and 1977, as against less than 25 percent for agriculture and industry (comprising mining and quarrying, manufacturing, and electricity, gas and water), combined.

Table 1.6

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (EJ).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.10	49.09	4.19	6.34	0.30		60.02
Net energy exports (–)	0.05	–38.15	–7.67	–2.66		–	–48.43
International bunkers (–)	–	–	–1.20				–1.20
Total primary energy requirements	0.15	10.94	–4.68	3.68	0.30	–	10.39
Electricity generation	–0.03	–0.09	–0.96	–0.92	–0.30	0.64	–1.66
Refineries		–10.85	10.45	–0.24		–0.02	–0.66
Gross final consumption	0.12	–	4.81	2.52		0.62	8.07
				1990			
Primary energy production	0.1	54.2	4.5	10.0	0.7		69.5
Net energy exports (–)	–	–37.4	–10.8	–4.7		–	–52.9
International bunkers (–)	–	–	–1.4				–1.4
Total primary energy requirements	0.1	16.8	–7.7	5.3	0.7	–	15.2
Electricity generation	–	–0.1	–1.3	–1.6	–0.7	1.1	–2.6
Refineries		–16.7	16.1	–0.5		–	–1.1
Gross final consumption	0.1	–	7.1	3.2		1.1	11.5
				2000			
Primary energy production	0.2	59.9	5.8	16.0	1.3		83.2
Net energy exports (–)	–	–29.4	–18.1	–6.2		–	–53.7
International bunkers (–)	–	–	–1.7				–1.7
Total primary energy requirements	0.2	30.5	–14.0	9.8	1.3	–	27.8
Electricity generation	–0.1	–0.1	–1.9	–3.8	–1.3	2.3	–4.9
Refineries		–30.4	29.1	–1.2		–0.1	–2.6
Gross final consumption	0.1	–	13.2	4.8		2.2	20.3

Concerning the primary fuel distribution of Arab TER, oil (including natural gas liquids) would account for about 60 percent of the total in 1985–2000, compared to 70 percent in 1977–1978 and 86 percent in 1960. This decline in relative terms is entirely due to a substantial projected growth in the utilization of natural gas in the Arab world.

The contribution of natural gas (net of reinjection) to TER is anticipated to rise from 23 percent in 1977–1978 to 35 percent in 1985–2000. Associated gas, which in the past was mostly flared or vented, is expected to be used on an expanding scale as an energy source and as raw material. Apart from providing the oil companies with the energy required for their operations and in their installations, it would increasingly serve as fuel for the generation of electricity, the desalination of water, the refining of crude oil, and the production of aluminum, cement, steel, glass, and other industrial products. It would also be used as feedstock in the expanding Arab petrochemical industry and in the conversion of heavy, sour crude oil into reconstituted light, sweet crude (see p. 9). It would finally be transformed into exportable liquid fuels, such as liquefied natural gas (LNG) and methanol. Associated gas, however, would probably not be produced in sufficient quantities in certain Arab countries to meet growing demand. This is because output depends on the amount of crude extracted, and this amount is subjected to various national and international, economic and noneconomic factors. Since a viable industry based on the utilization of natural gas as fuel and as raw material presupposes regular and durable supply sources, it is imperative that the plentiful resources of unassociated gas in the Arab world be developed at a rapid pace so as to ensure the security and adequacy of future supplies. This is one of the underlying assumptions in this study.

The balance of future Arab TER is represented by primary electricity and solid fuels. The share of primary electricity is expected to decline from 5 percent in the past two decades to 3 percent in 1985, before increasing gradually to reach again 5 percent by 2000. The rapid development of nuclear power (almost 22 percent per annum between 1985 and 2000) would mainly be responsible for the gains after 1985. Its contribution to total primary electricity generation is projected to rise from 18 percent in 1985 to 65 percent by the turn of the century, while the share of hydropower would decline from 81 percent to 34 percent, respectively, and solar electricity (and, to a much lesser extent, other primary sources) would account for less than 2 percent in 2000. Coming finally to solid fuels, their contribution to Arab TER is projected to average 1 percent in 1985–2000, compared to 2 percent in the past two decades.

The energy transformation sector (electricity generation and crude oil refining) is projected to claim an increasing share of TER, rising gradually from 21 percent recently to 22 percent in 1985 and 27 percent by the turn of the century. This is because (1) Arab electricity generation is projected to increase faster than TER between 1978 and 2000 (10.9 percent per annum as against 9.1 percent), thus implying a TER elasticity of energy loss (or waste heat) in power production greater than one, in spite of an estimated improvement in the average efficiency ratio of Arab conventional thermal electricity plants from 26 percent in 1978 to 32 percent in 2000, and (2) Arab refineries' own energy use and losses are expected to represent a growing proportion of refinery output (8.8 percent in 2000 against 6.0 percent recently) as a result of increasing sophistication in the Arab refining system, in spite of a growth rate in refinery output (8.8 percent) slightly below that of TER.

Arab TER net of energy transformation losses would go to final consumption sectors, in the form of petroleum products (65 percent in 2000 against 76 percent in 1978), natural gas (24 percent against 16 percent), electricity (11 percent against 7 percent), and solid fuels (1 percent).

Total Arab electricity generation from primary power (hydro, nuclear, solar, biogas, geothermal, wind) and conventional thermal power plants is projected at 176 terawatt-hours (TWh) in 1985, 300 TWh in 1990, and 650 TWh in 2000, as compared to 67 TWh in 1978. It is noteworthy that these forecasts, which are based on individual country programmes and perspectives in the electricity field, imply for 1978–2000 the same average elasticity of Arab power supply relative to GDP that prevailed during 1960–1977 (i.e., 1.6.) Although primary electricity is expected to make significant contributions to future Arab power output, its share in total generation would decline from 22 percent in 1978 to 13 percent in 1985, before increasing gradually (mainly as a result of the rapid development of nuclear power after 1985) to reach 19 percent by the turn of the century. As for Arab per capita electricity generation, it would increase from 438 kilowatt-hours (kWh) in 1978 to 1.41 gigawatt-hours (GWh) in 1990 and 2.33 GWh in 2000. At the end of the century Arab power consumption per head is expected to be 140 percent higher than the projected level in the rest of the developing world (compared to 20 percent in 1978), but it would represent only 20 percent of the level anticipated for the OECD area (compared to 7 percent in 1978).

Primary energy production in the Arab world would rise by 3.0 percent per annum, on the average, between 1978 and 2000, compared to 9.5 percent between 1960 and 1978. The performance during 1960–2000 can be broken down into the following growth rates: 12.2 percent in 1960–1973, 2.2 percent in 1973–1978, 4.6 percent in 1978–1985, 3.0 percent in 1985–1990, and 1.8 percent in 1990–2000. The share of crude oil in the total is projected to decline from 95 percent in 1975–1978 to 82 percent in 1985, 78 percent in 1990 and 72 percent in 2000. It is noteworthy that the price increases of 1973–1974 started a new era of low growth in Arab crude production, which, by virtue of the common Arab policy assumed in this study (see p. 6), is expected to continue in the future: Arab crude output is projected to increase by an average of 1.5 percent per annum between 1973 and 2000, in sharp contrast with the 12.0 percent growth that prevailed in the 1960–1973 period.

Future Arab output of primary fuels other than crude oil would principally include natural gas and natural gas liquids (NGL), which are expected to witness an impressive expansion (11.2 and 11.3 percent, respectively, between 1978 and 2000). Their contribution to total primary production is projected to rise for natural gas from less than 4 percent in 1978 to more than 19 percent by the turn of the century and for NGL from 1 percent to 7 percent. As for the remainder of Arab primary output, it would mostly consist of primary electricity, with solid fuels contributing negligible proportions.

Net energy exports from the Arab world would represent a declining share of total primary energy production, projected at about two-thirds in 2000, as compared with 78 percent in 1990, 83 percent in 1985, 91 percent in 1975–1978, and 95 percent in 1969–1970. The contribution of crude oil (net of reconstituted crude, see p. 9), which stood at 94 percent in 1974–1978, would decrease significantly during the projection period, so as to account for not more than 53 percent of the total at the end of the century. In contrast, petroleum products (comprising refinery products inclusive of bunkers, reconstituted crude, and NGL) are projected to represent an increasing proportion of net exports, their share rising from 5 percent in 1975–1978 to 36 percent in 2000. In absolute terms, net crude exports would decline from 19.0 Mb/d in 1977 to 18.5 Mb/d in 1985, 18.1 Mb/d in 1990, and 14.2 Mb/d by the turn of the century; whereas combined oil exports (crude and products) would increase from 19.9 Mboe/d in 1977 to 22.8 Mboe/d in 1985 and about 24 Mboe/d during the 1990s. Finally, the balance of net Arab energy exports (11 percent in 2000, compared to less than 2 percent in 1978) would consist of LNG and methanol shipments as well as gas exports by pipeline. These are expected to rise from 0.3 Mboe/d in 1978 to 1.3, 2.3, and 3.0 Mboe/d in 1985, 1990, and 2000, respectively.

Concerning the contribution of individual countries to total Arab energy exports, Saudi Arabia, Iraq, and Algeria must be singled out, in that order, since their combined share in the total is projected to rise gradually from 63 percent in 1977–1978 to 75 percent in 2000. Saudi Arabia would be responsible for 41 percent of net Arab energy exports in 1985 (43 percent of net oil exports), 43 percent in 1990 (47 percent of net oil exports), and 45 percent by the turn of the century (50 percent of net oil exports). The Kingdom's oil exports are projected to stand at 9.8 Mboe/d in 1985 (8.6 Mb/d of crude), 11.1 Mboe/d in 1990 (9.3 Mb/d of crude) and 11.7 Mboe/d in 2000 (7.0 Mb/d of crude). As for Iraq, it would account for 16 percent of net Arab energy exports in 1985 (17 percent of net oil exports), rising gradually to 17 percent in 2000 (19 percent of the net oil exports). Iraqi oil exports (mostly crude) would amount to 3.9 Mboe/d in 1985, 4.2 Mboe/d in 1990, and 4.6 Mboe/d at the end of the century. Finally, Algeria's contribution to future Arab energy exports would mainly be in the form of gas, transported by pipeline or shipped as LNG (90 percent of net Arab gas exports in 1985, 86 percent in 1990, and 76 percent in 2000); whereas its combined oil and gas exports would not exceed 13 percent of the Arab total during 1985–2000.

The World Outlook

The projections presented in Tables 1.4–1.6 were founded mainly on the assumption that the output of crude petroleum in the Arab world would be determined by an Arab long-term production policy that is based largely on consideration of its own present and future crude reserve position rather than on an analysis of the world market for oil. Since the Arab countries supply such a large proportion of the oil consumed in the world, and since energy has an important influence on global economic growth, it is clearly desirable to examine the other side of the equation by considering future world demand for energy in general and for oil in particular. The question whether Arab energy and oil exports as projected in this study would be adequate to meet world requirements depends very largely on the vigorousness of the policies adopted by OECD governments to expand energy production and reduce energy requirements per unit of their GDP, as well as on the level of GDP.

This study is about the Arab world; therefore, a full-scale investigation of future economic growth in the OECD area and of government policy measures that might be taken to stimulate production of energy and economy in its use goes beyond the scope of the present projections. Besides, ECWA is not the body to undertake any sort of authoritative analysis of this kind. However, the link between the Arab world and the rest of the world is of paramount importance, and the task will only be complete when this link is established. This could ideally be achieved by a "world energy council," but in the absence of such a body the problem can be best approached by a continuous dialogue between consumers and producers.

To provide a basis for such a dialogue, an attempt is made here to integrate the Arab world projections undertaken earlier in a purely illustrative picture of future world primary energy and oil supply and demand. For any such dialogue to be meaningful, however, the figures in this illustrative picture relating to non-Arab countries need to be replaced by authoritative forecasts supplied by the relevant parties.

The time horizon chosen for this exercise is 1990. This is because looking to an earlier target year, say 1985, would go against the raison d'être of the exercise, which is to examine what actions and policy measures should be adopted very early in the 1980s to influence the future, and there are long lead times on both the supply side and the demand side. On the other hand, looking to a time horizon far beyond 1990, say to 2000, would not be very helpful for policy planning due to the compounded uncertainties involved. Moreover, the outcome of actions and policy measures taken in the 1980s would certainly need to be taken into account in such longer-term forecasts.

The position in 1990 will be enormously influenced by what has happened in all years between now and 1990, because of the long lead times involved. And what happens during the intervening period (the 1980s) is largely influenced, on the one hand, by market reactions to the position of the economy, such as GDP growth and the relative price of energy, and, on the other hand, by government policy. The basic assumptions will have to deal with both of these.

This exercise, therefore, is based on:

1. One assumption about economic growth in the OECD area during the 1980s. The average growth rate adopted is 3 percent per annum, which is a plausible target provided that energy is not the major constraint.

2. Two alternative assumptions concerning the "vigour" with which OECD governments will pursue their energy policies during the 1980s, one moderate or restrained, and one forceful or vigorous.

3. Two alternative assumptions relating to the evolution of the price of oil in real terms during the 1980s, one constant at today's level, and one gently rising by an average of 2 percent per annum.

The quantitative picture presented in Table 1.7 below is based for the Arab world on the findings of this study as shown in Table 1.5 and for the rest of the world on a selective analysis of a great number of existing energy and oil supply and demand projections—bearing in mind the basic assumptions outlined above.

It should be emphasized that the illustrative figures shown in Table 1.7 are in no sense forecasts of what will happen. They are not even conditional

Table 1.7

Illustrative Picture of World Primary Energy and Oil Supply and Demand[a], 1990 (Mboe/d).

OECD Government Energy Policies, 1980–1990:	Restrained				Vigorous			
Real Price of Oil, 1980–1990:	Constant		Rising 2 Percent Per Annum		Constant		Rising 2 Percent Per Annum	
	Total Energy	Oil	Total Energy	Oil	Total Energy	Oil	Total Energy	Oil
OECD								
Supply	70	16	74	19	74	17	77	20
Demand	108	52	106	50	105	49	103	47
Surplus (+) or Deficit (–)	–38	–36	–32	–31	–31	–32	–26	–27
Arab World								
Supply	33	28	33	28	33	28	33	28
Demand	8	5	8	5	8	5	8	5
Surplus (+) or Deficit (–)	25	23	25	23	25	23	25	23
Non-Arab OPEC[b]								
Supply	14	11	14	11	14	11	14	11
Demand	9	7	9	7	9	7	9	7
Surplus (+) or Deficit (–)	5	4	5	4	5	4	5	4
Rest of WOCPE[c]								
Supply	20	9	22	11	20	9	22	11
Demand	19	8	20	9	19	8	20	9
Surplus (+) or Deficit (–)	1	1	2	2	1	1	2	2
CPEs[d]								
Surplus (+) or Deficit (–)	–	–	–	–	–	–	–	–
World								
Surplus (+) or Deficit (–)	–7	–8	–	–2	–	–4	6	2
Memorandum Item								
OPEC								
Supply	45	38	45	38	45	38	45	38
Demand	14	10	14	10	14	10	14	10
Surplus (+) or Deficit (–)	31	28	31	28	31	28	31	28

[a]Demand includes bunkers.
[b]Ecuador, Gabon, Indonesia, Iran, Nigeria, and Venezuela.
[c]Rest of the world outside centrally-planned economies.
[d]Centrally-planned economies of Asia (China, Democratic People's Republic of Korea, Mongolia, and Viet Nam) and of Europe (Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, and USSR).

Assumptions:

1. OECD area GDP growth rate, 1980–1990: 3 percent per annum.
2. Arab world energy and oil supply and demand, 1990: from Table 1.5.

Note:

A dash (–) indicates nil or negligible quantities.

forecasts of what would happen under the basic assumptions, since they mostly lead to imbalances in world energy and/or oil supply and demand, which cannot happen in the real world. Moreover, the figures represent in principle the sum of the amounts that each country would wish to produce and consume in 1990, given the capacity it would have built up and the policies it would have implemented in the intervening years on the basis of the broad key assumptions on growth, policy, and price adopted in this exercise.

The main conclusion that can be drawn from an examination of Table 1.7 is that, on the basis of the collective Arab oil production policy proposed in this study (see p. 6), the world supply and demand situation in 1990 would not seem to be as alarming for total primary energy as it is for oil. In fact, three cases out of four show a balance or even a surplus in total energy. As for oil, the outlook changes significantly, and three cases out of four show a global deficit. This discrepancy between the energy position and the oil position implies that future fuel-mix availabilities would not match the preferred fuel-mix pattern. The gap is most pronounced for oil, where a deficit ranging from 3 to 11 percent of world demand is shown in the first three cases. In this connection, it is worth recalling the large impact that a shortage of 3 percent in oil supply availabilities (2 Mb/d) had on oil prices and markets in 1979.

Accordingly, the vigorous policy–rising price case seems to be the only one out of the four in which it can be reasonably assumed that the world would not face a shortage of oil and energy in 1990.

TWO

INTRODUCTION: THE ARAB WORLD IN THE INTERNATIONAL ENERGY SET-UP

It is hard to overdramatize the importance of oil as a source of energy. World oil consumption has increased tenfold since 1940, fourfold since 1955 and has nearly doubled since 1965 [1]. The share of oil in world energy requirements has doubled over the past 25 years to reach more than 50 percent today [2].

Its relatively cheap price and its comparative advantage over coal in terms of versatility, cleanness, and accessibility increased progressively the demand for oil in the 1940s and early 1950s. Later on, the almost continuous fall in the real price of oil (by over 60 percent between 1958 and 1970) led to a considerable rise in oil-intensive investments, which, coupled with an unprecedented growth of the world economy, generated high rates of growth in demand (7.5 percent during 1950–1973).[1] Consumption continued to rise after the price increases of 1973–1974, albeit at a slower pace (3.3 percent during 1974–1978). The low rate of implementation of energy conservation measures in major countries, delays and downward revisions in nuclear programmes, and a slow progress in the development of other energy alternatives, led governments in the main oil-consuming countries to realize that their plans to shift away from oil as the major fuel would take much more time than they originally anticipated. World oil consumption in 1978 was, in fact, the highest ever.

Oil is not evenly distributed among nations. The developing countries have most of it (80 percent), while the industrialized world consumes most of it (81 percent). Two extreme examples are, in the first group, Saudi Arabia, which possesses 26 percent of world proved reserves and accounts for only 0.3 percent of world oil consumption, and, in the second group, the USA, which owns 4 percent of reserves and yet consumes some 30 percent of the world total. This worldwide imbalance has increased over the years and has forced a growing interdependence of nations in the energy field. Internationally traded energy (measured by world imports of commercial energy) increased from 0.6 Btoe in 1957 to 1.3 Btoe in 1967 and 2.4 Btoe in 1977. Oil accounted for 80, 89, and 88 percent of these amounts, respectively. At the same time, the proportion of world oil output that was traded increased from 52 percent in 1957 to 62 percent in 1967 and 67 percent in 1977 and mainly consisted of crude petroleum (64, 75, and 83 percent, respectively).

Two groups of countries have emerged as the leading partners in this immense and intricate world oil trade system, namely, OPEC countries as the main exporters, and OECD countries as the main importers. During 1970–1977, on the average, the former were responsible for 86 percent of world crude oil exports, while the latter accounted for about 81 percent of world crude imports. Moreover, OPEC provided 89 percent of OECD's crude import needs during that period (see Appendix 2).

The seven Arab countries that are members of OPEC (Algeria, Iraq, Kuwait, LAJ, Qatar, Saudi Arabia, and UAE) accounted in 1978 for over 65 percent of OPEC crude exports, compared to 61 percent in 1973–1974 [3], and this upward trend

[1] In this study all growth rates have been estimated by fitting semilogarithmic regression trends to the historical data.

is likely to continue, as the present study will show. That is to say, these countries carry today, and will carry tomorrow more than today, considerable weight within OPEC and have the ability to influence the course of events on the international scene through OPEC action. Besides, most of the important decisions taken by OPEC have been initiated in the Arab world.

The increasingly dominant role of the Arab world in the international petroleum setup is clearly demonstrated in the following facts and figures.

At the beginning of 1980, Arab countries accounted for more than 53 percent of world proved crude oil reserves. More than 85 percent of the remaining reserves in super-giant fields[2] around the world lie in the Arab Middle East. During 1954–1979 cumulative Arab crude output represented only 27 percent of the gross additions to the area's proved reserves over that period (381 Bb), as against 52 percent for the rest of the world. As a result, Arab reserves increased from 63 Bb at the beginning of 1954 to 341 Bb at the beginning of 1980 (see Appendix 3).

Over half a century has now passed since the first barrel of crude was commercially produced in the Arab world (Iraq, 1928). Up to the end of 1953 the area had accounted for only 5 percent of cumulative world crude output. During the second half of that period (1954–1979), however, the percentage jumped to 30, when Arab cumulative production reached 26 times the output over 1928–1953, compared to three times for the rest of the world. Annual production during 1954–1979 sustained an average growth rate of 9.9 percent, as against 5.5 percent for the rest of the world. Moreover, Arab output in 1979 was almost equal to the cumulative output of the first 30 years of production, exceeding 8 Bb or 35 percent of the world total. Cumulative production over the eight years 1972–1979 (56 Bb) exceeded all the Arab world had ever produced before (52 Bb). The area's reserves to production (R/P) ratio has been declining almost continuously from 106 to 1 in 1959 to 53 to 1 in 1969 and 43 to 1 in 1979, whereas the ratio for the rest of the world stood in 1979 at its average level of the 1950s (20 to 1).

In the 1970s the Arabs have provided the world with an average of 55 percent of its crude import needs, with the percentage fluctuating around an upward trend. In 1977 OECD countries absorbed 78 percent of Arab crude exports, compared to 85 percent in 1970. While a comparison of the two percentages reflects growing outlet diversification on the part of the Arab crude exporting countries, the OECD area's dependency on Arab crude has increased from 57 percent (of total crude imports) in 1974 to nearly 60 percent in 1977. The USA has been the most striking example of this dependency increase: the Arab world accounted in 1977 for 50 percent of US crude imports, as against less than 22 percent in 1974. Japan's case is also noteworthy, although less spectacular, with 62 percent in 1977 compared to less than 51 percent in 1974 and less than 41 percent in 1971 (see Appendix 2).

In contrast to its key role on the international crude oil scene, the Arab world was responsible in 1978 for not more than 3.5 percent of the world output of refined products. Arab primary refining capacity stood at about 3.3 Mb/cd in mid-1980, compared with a crude sustainable productive capacity approaching 26 Mb/d. Refinery output, after increasing steadily up to 1970 (6.6 percent per annum during 1960–1970), more or less stagnated afterwards through 1976, before gaining new momentum as of 1977 (9.0 percent per annum between 1976 and 1978). The mediocre performance in the 1970s (1.4 percent per annum between 1970 and 1978) reflected the continuous decline after 1970 of Arab net exports of petroleum products (inclusive of bunkers), which still stood in 1978 at 22 percent below their level of 1970 (see Appendix 1). This decline was probably due to:

1. Difficulties in marketing heavy products, which constitute about 70 percent of the Arab refinery output mix.
2. A worldwide surplus refining capacity in all areas outside the USA and Japan (this explains why the latter country has been the main single client of Arab refiners,

[2] Super-giant fields are defined as fields with remaining proved reserves of more than 10 Bb. There are six such fields in the world, four of which are in the Arab Middle East.

particularly Bahrain, Kuwait, and Saudi Arabia—see Appendix 2).
3. The recession in the Western world.
4. A more relaxed attitude on the part of Arab oil producers towards exporting refined products after the events of 1973-1974, which changed international crude trading from a buyer's market to a seller's market.
5. A rise in the domestic demand for products greater than the increase in refining capacity in some Arab countries.

The downward trend in Arab product exports, however, is likely to be reversed in the future, as the present study will show.[3]

From among the Arab oil producers (13 at present), Saudi Arabia must be singled out, because of the Kingdom's dominant position in the Arab world and its dramatically ever-rising importance as the "residual supplier" of the world. Almost one-half of Arab proved oil reserves lie in Saudi Arabia. This country has the largest reserves in the world and is the second largest crude producer and the first exporter. During 1954-1979 cumulative crude output represented 21 percent of the gross additions to the Kingdom's proved reserves, which in turn accounted for 46 percent of total Arab additions. Saudi Arabia averaged in recent years (1976-1979) some 44 percent of Arab crude output and 15 percent of total world production. In 1979 output averaged more than 9.5 Mb/d and sustainable productive capacity 10.6 to 10.8 Mb/d (see Appendix 3). The Kingdom accounted for 26 percent of world crude exports in 1977, compared with 14 percent in 1970. Moreover, Saudi Arabia provided 27 percent of the crude imports needs of the OECD area in 1977, as against 13 percent in 1970 (see Appendix 2).

Appendices 1, 2, and 3 give more details on the Arab world's energy situation and role in the international energy setup.

The evolution of the energy supply and demand situation of the Arab world during the period 1960-1978 is summarized in the form of annual energy balances constructed and presented in Appendix 1. A brief analysis of these balances is given below.

Total Arab primary energy requirements (TER) increased between 1960 and 1977 by an average annual rate of 10.4 percent, as against 7.0 percent for gross domestic product in real terms (GDP). The GDP elasticity of TER[4] averaged 1.44 during the period, compared to 1.05 for the OECD area. This reflects the need for greater energy demand growth in a developing region than in a highly industrialized area to achieve a given economic growth rate. A closer look at the period under review shows a significant drop in the Arab world's elasticity from an average of 1.33 in 1960-1972 to 1.01 in 1973-1977. This is probably due to increased economic activity in the area as a result of higher oil revenues since 1973, which manifested itself more particularly in nonenergy intensive sectors (construction, services, government, etc.). In fact, Arab value added in these sectors increased by more than 69 percent between 1972 and 1977, as against less than 25 percent for agriculture and industry (comprising mining and quarrying, manufacturing, and electricity, gas, and water) combined (see Table A8.2).

Concerning the primary fuel distribution of Arab TER, oil accounted for 70 percent of the total in 1977-1978, compared with 86 percent in 1960. This decline in relative terms is entirely due to a considerable growth in natural gas utilization in the Arab world, its share in TER increasing from 7 percent in 1960 to 23 percent in 1977-1978. Primary electricity has been responsible for around 5 percent of TER throughout the period and has consisted solely of hydropower in Algeria, Egypt, Iraq (as of 1972), Lebanon, Morocco, Sudan (as of 1962), the SAR, and Tunisia. Finally, solid fuels only represented 2 percent of Arab TER in the past two decades, with the percentage lightly fluctuating around a slightly downward trend.

The energy transformation sector (electricity generation and refineries), which absorbed about

[3] A detailed analysis of the question is presented in Chapter 5.

[4] In this study all elasticities have been estimated by fitting power regression curves to the historical data.

27 percent of Arab TER in the 1960s, accounted for 21 percent recently. This is because 1) refinery output, and consequently refineries' own energy use and losses, increased at a much slower pace than TER during the period under review (4.7 percent against 10.3 percent, respectively), and 2) the average efficiency ratio of Arab conventional thermal power plants improved from less than 23 percent in 1960 to almost 26 percent in 1978, thus reducing energy loss (or waste heat) per unit of electricity output. Besides, had gross electricity generation not increased at a faster rate than TER during the period, the decline in the percentage of TER used in energy transformation would have been more pronounced.

Arab TER net of energy transformation losses went to final consumption sectors in the form of petroleum products (75 percent in 1977-1978 against 91 percent in 1960), natural gas (17 percent in 1977-1978 against 1 percent in 1960), electricity (7 percent in 1977-1978 against 4 percent in 1960), and solid fuels (1 percent in 1977-1978 against 4 percent in 1960).

The Arab world produced 67 TWh of hydro and conventional thermal electricity in 1978, witnessing an average annual growth of 11.7 percent since 1960. The share of hydropower in total electricity generation rose from 22 percent in 1960 to 34 percent in 1969, before declining gradually in the 1970s to revert back to 22 percent in 1978. Although other primary sources (nuclear, solar, geothermal, wind, biogas) are expected to make significant contributions to future Arab power output, the share of primary electricity in total generation should continue to decline to 13 percent in 1985, before increasing again to reach 19 percent by the turn of the century. As for Arab per capita electricity generation, it increased from 86 kWh in 1960 to 181 kWh in 1970 and 438 kWh in 1978, implying an average annual growth of 9.5 percent between 1960 and 1978. Arab power supply per head in 1978 was 20 percent higher than in the rest of the developing world but represented less than 7 percent of the per capita electricity output in the OECD area.

Total Arab primary energy production rose by 9.5 percent per annum, on the average, between 1960 and 1978. This performance can be broken down into a growth rate of 12.2 percent between 1960 and 1973 and a rate of 2.2 percent between 1973 and 1978. The marked slowdown after 1973 reflects a parallel reduction in the growth of Arab crude oil output, which came as a result of the oil embargo and price increases of 1973-1974, the recession in the Western world, and conservationist production policies in certain Arab countries. Primary energy production peaked at 22.0 Mboe/d in 1977 before dropping to 21.2 Mboe/d in 1978. The share of crude oil in the total decreased from 99 percent in the early 1960s to 95 percent in 1975-1978. The remainder consisted of natural gas (3.6 percent in 1978 against 0.7 percent in the early 1960s), natural gas liquids (1.2 percent against 0.1 percent), hydroelectricity (0.5 percent against 0.3 percent) and solid fuels (less than 0.1 percent against 0.2 percent).

Net exports of energy from the Arab world represented in recent years 91 percent of primary energy production, after having peaked at 95 percent in 1969-1970, and consisted of crude oil, petroleum products, and, as of 1964, liquefied natural gas (LNG). Crude oil had the lion's share in the total, with its proportion increasing from 86 percent in the early 1960s to 94 percent since 1974, thus reflecting the growing importance of the Arab world as a major crude supplier to the rest of the world. Petroleum products, in the form of refinery products (inclusive of bunkers) and natural gas liquids, reduced their contribution to total exports from 14 percent in the early 1960s to 5 percent as of 1975. The balance was accounted for by LNG with almost 2 percent in 1978 (1 percent in 1973-1977).

THREE
METHODOLOGY

This chapter presents the methodological framework within which the energy projections are carried out in Chapters 4 to 8. After an introduction to the energy balance sheets used in this study, the projection model is explained, followed by a presentation of the methodology and by the sequence of the projections in the model application. Price assumptions are also discussed. Finally, the methodology is compared to other available methodologies used in similar exercises.

ENERGY BALANCES

The usefulness of basic energy statistics is considerably improved when the data are expressed in a single common unit suitable for uses such as the estimation of total energy requirements (TER), projections of energy supply and demand, and the study of energy conservation and substitution. The approach adopted in this study for converting the basic data into a common unit is explained in detail in Appendix 1, which also presents the application of the approach to the Arab world. The outcome is annual energy balance sheets (energy balances, for short) of the Arab world for the period 1960–1978 (see Appendix 1), which constitute the historical background against which the projections are carried out.

Energy balances are a consistent framework for presenting (by type of fuel: solid fuels, crude oil, petroleum products, natural gas, and electricity) the domestic supply, imports and exports, transformation, and consumption of energy. This framework is again used in the projection model, as explained in the following section.

The common unit adopted for presenting the historical as well as the projected energy balances is the metric ton of oil equivalent (toe), which is an approximate measure of the average heat content of a ton of crude oil. An alternative unit that is also commonly used is the barrel per day of oil equivalent (boe/d), which is approximately equal to 50 toe. Yet another energy unit of more recent use is the terajoule (TJ), which is approximately equal to 24 toe (see Appendix 1).

THE MODEL

The projections are carried out in the framework of a regional energy balance model, in the consolidated form presented in Table 3.1. The 38 variables included in the model are defined directly below the table. The identity relationships between the variables, which are inherent to the structure of the energy balance model, are listed after the variables.

The denomination and contents of the different rows and columns of the energy balance model (Table 3.1) are the same as for the 1960–1978 energy balance sheets appearing in Appendix 1, except for the following:

1. The second row in Table 3.1 (net energy exports) is the aggregation or algebraic sum of the "Imports" row (row 2) and the "Exports" row (row 3) in Appendix 1.

2. No provision is made here for changes in stocks (row 5 in Appendix 1), since it is normally assumed that such changes are nil *ex ante*.

Table 3.1

Energy Balance Model.

	Solid fuels	Crude Petroleum	Petroleum products	Natural gas	Primary electricity	Electricity	Total
Primary energy production	PSF	PCP	PGL	PNG	PPE		P
Net energy exports (–)	–XSF	–XCP	–XPP	–XNG		–XEL	–X
International bunkers (–)	–	–	–BNK				–B
Total primary energy requirements	TSF	TCP	TPP	TNG	TPE	TEL	TER
Electricity generation	–ESF	–ECP	–EPP	–ENG	–EPE	ELG	–W
Refineries		–RCP	REF	–RNG		–REL	–R
Gross final consumption	CSF	–	CPP	CNG		CEL	GFC

Notes:

1. The projections cover the period up to 2000 with the following bench-mark years: 1985, 1990, and 2000.
2. Projected magnitudes of the 38 variables in the model are expressed in million toe (Mtoe), with one significant digit after the decimal point in the case of the 1985 estimates, but rounded off to the nearest integer in the case of the 1990 and 2000 estimates.
3. A dash (–) indicates nil quantities or figures below 0.05 Mtoe in 1985 and below 0.5 Mtoe in 1990 and in 2000.
4. A blank means that the corresponding item is not applicable.

Model Variables

The 38 variables of the energy balance model are defined in the order in which they appear in Table 3.1. (reading down the columns).

PSF: Production of solid fuels.
XSF: Net exports of solid fuels.
TSF: Total domestic requirements of solid fuels.
ESF: Solid fuels burnt in thermoelectricity plants.
CSF: Gross final consumption of solid fuels.
PCP: Production of crude petroleum.
XCP: Net exports of crude petroleum.
TCP: Total domestic requirements of crude petroleum.
ECP: Crude petroleum used directly as fuel in thermoelectricity plants.
RCP: Crude petroleum entering refineries.
PGL: Production of natural gas liquids (NGL).
XPP: Net exports of refinery products and NGL.
BNK: Petroleum products used in international bunkering operations.
TPP: Total domestic requirements of petroleum products.
EPP: Petroleum products fueling thermoelectricity plants.
REF: Refinery output.
CPP: Gross final consumption of petroleum products.
PNG: Production of natural gas.
XNG: Net exports of natural gas.
TNG: Total domestic requirements of natural gas.
ENG: Natural gas fueling thermoelectricity plants.
RNG: Refineries' own use of natural gas.
CNG: Gross final consumption of natural gas.
PPE: Production of primary electricity.
TPE: Total domestic requirements of primary electricity.
EPE: Primary electricity fuel input equivalent.
XEL: Net exports of electricity.
TEL: Net trade in electricity.
ELG: Gross electricity generation.
REL: Refineries' own use of electricity.
CEL: Gross final consumption of electricity.
P: Total production of primary energy.
X: Total net energy exports.
B: International bunkers.
TER: Total domestic primary energy requirements.
W: Waste heat (or energy loss) in electricity generation.
R: Refineries' own energy use and losses.
GFC: Gross final consumption.

Model Structural Identities

The following identity relationships between the 38 variables are inherent to the structure of the energy balance model. They are listed by order of sequential use in the projections, as explained in the next section.

1. TPP = CPP - REF + EPP
2. TCP = ECP + RCP
3. XCP = PCP - TCP
4. R = RCP + RNG + REL - REF
5. XPP = PGL - TPP - BNK
6. TNG = PNG - XNG
7. CNG = TNG - ENG - RNG
8. TPE = PPE
9. EPE = TPE
10. W = ESF + ECP + EPP + ENG + EPE - ELG
11. TEL = -XEL
12. CEL = TEL + ELG - REL
13. XSF = PSF - TSF
14. CSF = TSF - ESF
15. P = PSF + PCP + PGL + PNG + PPE
16. X = XSF + XCP + XPP + XNG + XEL
17. B = BNK
18. TER = TSF + TCP + TPP + TNG + TPE + TEL
19. GFC = CSF + CPP + CNG + CEL.

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3. The "Statistical differences" row (row 9) in Appendix 1 is cancelled here because 1) unexplained statistical discrepancies do not exist *ex ante,* and 2) unlike the corresponding item under column 2 in Appendix 1, item RCP in Table 3.1 concerns only crude petroleum entering refineries and does not include natural gas liquids (NGL) entering or naphtha backflows into refineries. Thus, item CCP in Table 3.1 (gross final consumption of petroleum products), unlike the corresponding item in Appendix 1 (row 10, column 3), includes all domestically consumed NGL.

METHODOLOGY AND SEQUENCE OF THE PROJECTIONS

Nineteen out of the 38 variables in the energy balance model are projected *exogenously* to the model, in Chapters 4 to 8. The 19 remaining variables are then *endogenously* determined using the 19 structural identities listed above.

Future magnitudes of the 19 exogenous variables are estimated for 1985, 1990, and 2000 according to methodologies explained in detail in Chapters 4 to 8. PCP is projected in Chapter 4 using a (hypothetical) clearly defined production policy for Arab oil-producing countries. The four exogenous variables in the "Refineries" row (REF, RCP, RNG, and REL) of Table 3.1, as well as CPP and BNK, are estimated in Chapter 5 using a separate model based on: an assumed policy for the export of refined products from the Arab world, perspectives for Arab refineries' energy use and losses and for Arab bunkering activities, and an econometric forecasting of Arab gross final consumption of petroleum products. Three exogenous natural gas variables (PGL, PNG, and XNG) are projected in Chapter 6 on the basis of relevant Arab country programmes and perspectives in the natural gas field. Seven exogenous electricity variables (PPE, ELG, ESF, ECP, EPP, ENG, and XEL) are estimated in Chapter 7 on the basis of programmes and perspectives of the 21 Arab countries in the field of primary (hydro, nuclear, solar, biomass, geothermal, wind) and conventional thermal electricity. Finally, PSF and TSF are projected in Chapter 8 for the few Arab countries that are likely to be producers and/or users of solid fuels.

The following listing shows the sequence in which the 38 variables of the energy balance model are determined. This sequence may not always coincide with the chronological order in which the variables are actually estimated in the coming chapters. This applies to variables PGL, ECP, and EPP, the projected values of which are necessary for the determination of most of the oil variables, and to variable ENG.

Exogenous variables are followed in the list by a reference (in parenthesis) to the chapter where they are actually estimated. Endogenous variables are followed by a reference (in parenthesis) to the structural identity (see above) that serves to determine them.

1. PCP (Chapter 4).
2. CPP (Chapter 5).
3. PGL (Chapter 6).
4. ECP (Chapter 7).
5. EPP (Chapter 7).
6. REF (Chapter 5).
7. TPP (identity 1).

8. RCP (Chapter 5).
9. TCP (identity 2).
10. XCP (identity 3).
11. RNG (Chapter 5).
12. REL (Chapter 5).
13. R (identity 4).
14. BNK (Chapter 5).
15. XPP (identity 5).
16. PNG (Chapter 6).
17. XNG (Chapter 6).
18. TNG (identity 6).
19. ENG (Chapter 7).
20. CNG (identity 7).
21. PPE (Chapter 7).
22. TPE (identity 8).
23. EPE (identity 9).
24. ELG (Chapter 7).
25. ESF (Chapter 7).
26. W (identity 10).
27. XEL (Chapter 7).
28. TEL (identity 11).
29. CEL (identity 12).
30. PSF (Chapter 8).
31. TSF (Chapter 8).
32. XSF (identity 13).
33. CSF (identity 14).
34. P (identity 15).
35. X (identity 16).
36. B (identity 17).
37. TER (identity 18).
38. GFC (identity 19).

PRICE ASSUMPTIONS

Although energy price variables are not explicitly introduced in the model, the underlying assumption is that changes in the real price of oil during the projection period (1980–2000) would not have a substantial effect on oil production and consumption.

The first reason for making this assumption is that prices are not expected to increase significantly faster than the rate of inflation[1] on the following grounds. On the one hand, it is believed that the real price of oil is not likely to fall because 1) there is a widespread recognition that oil will remain the major energy source during the projection period, 2) it clearly appears from available statistics that oil demand in the industrialized world has proved to be less elastic to price than many had originally expected in 1974,[2] 3) the present United States administration has decided to adopt a nonconfrontation external energy policy and has planned to gradually raise domestic oil prices to world levels, and 4) a number of important energy production programmes recently initiated in the industrialized world could not be viable if oil prices were to drop significantly. Anyhow, even if the real price were to fall, consuming countries would be prepared to consider the establishment of a floor price for landed (imported) oil in order to protect their search for and exploitation of higher-cost domestic crude and to promote the development of energy alternatives.

On the other hand, it is believed that the real price of oil is not likely to increase significantly as long as the demand for Saudi Arabian oil does not grow out of proportion to the country's capacity. In fact, Saudi Arabia is now the residual supplier of the world oil market (see p. 23). The Kingdom possesses at present a flexibility of output that is more than sufficient to counterbalance any fluctuations in world oil supply and demand for some time. This balancing role has given Saudi Arabia the ability to exert a decisive influence on prices, which, coupled with the country's moderate positions on the price issue since 1974, supports the above assumption. It should be noted, however, that Saudi Arabia cannot control both the price and its output level. In other terms, if it were to achieve a certain (high) level of oil production to meet world demand, it would no longer be able to use its output flexibility to control the price[3], unless the Kingdom could manage to keep its oil production capacity at levels always far ahead of output requirements.

[1] The volume-weighted average of official OPEC prices was approximately $29/b as of 1 January 1980 ($26/b for the "marker" crude).

[2] Net oil imports of the OECD area exceeded in 1977 their all-time record of 1973 by nearly 4 percent [4].

[3] This actually happened after the cutbacks in Iranian production as of November 1978 (see p. 35).

The second reason for making the assumption is that even if real prices were to rise during the projection period, their relation to the supply-demand balance may not, to a certain extent, be quite significant. This is illustrated by a hypothetical, but not unrealistic, case represented in Figure 3.1, whereby the oil supply curve (S) is an increasing function of price and the demand curve (D) a decreasing function of price. The supply and demand curves are spotted for four time bench marks. S is assumed to decrease with time; i.e., for a given fixed oil price the corresponding supply is in period 2 smaller than in period 1. This reflects reserve depletion and higher costs attached to enhanced recovery and new reserve discoveries. The demand curve's elasticity to price is assumed to be almost negligible in period 1, increasing in subsequent periods as demand grows with time. This means that while demand will continue to rise as economic growth proceeds, it will increase at a lower rate at higher prices, reflecting the advent of alternative energy sources, which would become competitive at a certain price level. The graph also indicates the supply-demand balance in each period, i.e., the meeting point (SD) of curves S and D. An examination of these four meeting points suggests the (hypothetical) conclusion that actual production (and consumption) of oil would continue to increase even with rising prices but only up to a certain (high) level beyond which it might level off and start declining. This may imply that, unless some really drastic change takes place on the oil price scene, the price variable is not anticipated to have a drastic influence on energy futures.

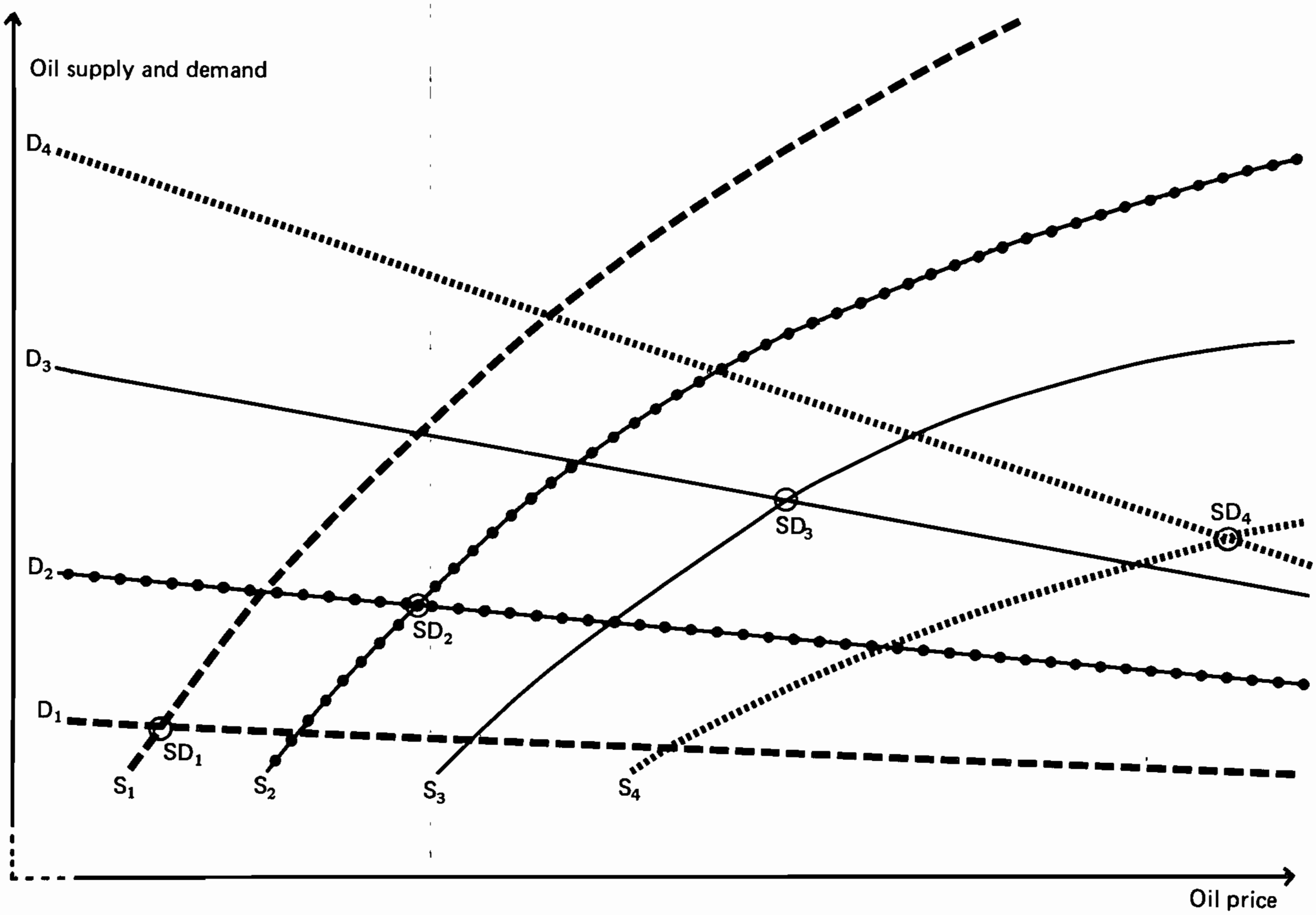

Figure 3.1. Hypothetical representation of oil supply and demand with respect to oil price and time.

COMPARISON WITH OTHER METHODOLOGIES

An overwhelming number of energy projections have been published in recent years, particularly since the oil price increases of 1973-1974. Seventy-nine of the most significant ones for the future world oil and energy situation, issued between February 1976 and February 1980, are listed in Appendix 10 in the form of an annotated index. Thirty-two of these cover the world by major countries or groupings, and another 18 deal solely with the USA, a nation that will play a key role in the future world energy balance.

A methodological assessment of all these projections is not possible in the context of this study, nor is it feasible in view of the nonavailability of "assessable" methodologies in a great number of cases. Two are selected here for examination, which are considered worldwide among the most important to date. The first is OECD's *World Energy Outlook* [5], and the second is MIT/WAES's *Energy: Global Prospects 1985-2000* [2], both published in 1977. Specific comments on these two studies are presented in Appendix 4 and Appendix 5, respectively. Only a summary of methodological remarks is given below.

Both reports consider constant price assumptions up to 1985. In fact, the OECD report assumes a constant oil price in real terms ($11.51/b in 1975 dollars, for the "marker" crude) throughout the projection period (1974-1985), while the two most plausible scenarios retained by the WAES report up to 1985 make the same assumption ($11.50/b). For 1985-2000 the latter report examines both a continuation of the constant trend and the possibility of a gradually rising price (to $17.25/b by 2000).

OECD

Broadly speaking, the OECD projections are carried out within a methodological framework similar to the one adopted in the present study. However, the last two rows of the energy balance model ("Refineries" and "Gross final consumption") are excluded from the OECD model, while the first two columns ("Crude petroleum" and "Petroleum products") are integrated in one ("Oil and NGL"). This integration clearly avoids the study of the refining sector–hence the exclusion of the "Refineries" row–which would have not only provided more refined projections but also shed some light on OECD's anticipations concerning this delicate producers/consumers issue.

Oil imports, by far the most important variable in the OECD projections, emerge as a residual after subtracting future supplies of all forms of energy (estimated on the basis of government forecasts and assumptions made by the OECD secretariat) from total energy requirements (projected using government forecasts and secretariat assumptions concerning the growth in gross domestic product). Adopting this approach simply on the grounds that, to a large extent, it mirrors the actual situation is not sufficiently convincing to counterbalance its two major shortcomings; namely, that small errors in the projection of the other variables lead to large (additive) errors in the estimation of oil imports, and that "the supplies of crude oil offered by OPEC for export are assumed to match the potential world demand for OPEC oil."

Concerning the alternative scenarios to the central reference case, which are examined in the OECD report, it is believed that their methodology raises some questions as to their effectiveness. A central accelerated policy case is derived from the central reference case by adjusting energy consumption and production to savings and output increases that are expected to accrue from the implementation of strong conservation and domestic supply expansion policies. However, the possible structural interactions between such policy changes and economic growth are not investigated.

A low growth scenario and a high growth scenario are also derived from the central reference case by adjusting TER and electricity output in direct proportion to the assumed downward or upward change in gross domestic product. Such proportional adjustments in TER go against the raison d'être of these alternative growth scenarios, which are, according to the report, "constructed to show the sensitivity of oil import estimates to different assumed rates of economic growth."

A more detailed review and appraisal of the OECD report can be found in Appendix 4.

WAES

The methodology of the WAES report is more complete than that of the OECD report. Once detailed assessments are carried out, by country or region, of future energy (desired) demand and (potential) supply (using national and regional economic scenarios based on a set of global assumptions concerning world economic growth, energy price, oil discoveries and production limits, national energy policy response, principal replacement fuel), such assessments are aggregated, and a world supply-demand integration model is applied to try to meet all end-use energy demands and achieve a balance between total energy supply and demand. The technique used (a highly constrained linear programming model), however, is not designed to close the supply-demand gaps completely. Actually, the results of the constrained model integrations for 2000 show that, while the prospective gaps between desired demand and potential supply can be reduced, a certain "unfilled demand" remains.

The national teams that devised and applied the methodology of the WAES report came from 11 OECD countries (which accounted in 1976 for more than 90 percent of the total OECD area gross domestic product) plus Mexico and Venezuela. The great majority of oil-exporting countries did not participate in the project. There were no participants from the Arab world either. It is not surprising, therefore, that the national assessments looked more carefully into the oil-importing industrialized countries than into others. It is interesting to note, on the other hand, that the most important parts of the report were prepared by British Petroleum (BP) staff.

Finally, the different "plausible scenarios" presented in the WAES report appear to be quite sensitive to the "gross additions to oil reserves" variable. In fact, it is sufficient to raise the magnitude assumed for that variable by 10 billion barrels per year to overrule the conclusions reached in the report. This possibility is also a "plausible" one, since the text indicates that "the assumptions made for gross additions to oil reserves may be considered by some observers to be conservative. Gross addition to reserves may indeed be higher than our high case of 20 billion barrels per year."

A more detailed review and appraisal of the WAES report can be found in Appendix 5.

FOUR
CRUDE PETROLEUM

The Arab world plays and will continue to play a key role on the international oil scene. Arab countries account for some 60 percent of world crude petroleum exports and meet about two-thirds of the net crude import needs of the OECD area. A well defined, clearly spelled out Arab long-term oil production policy would, thus, constitute a factor of prime importance in lifting the uncertainty about future world oil supplies that has resulted from the tight market situation prevailing since the Iranian revolution. It would, hence, provide a basis for a much needed concerted action between producers and consumers, allowing the latter to initiate the long-term adjustments in their economies necessary to ensure that future oil demand would not exceed available supplies.

This is the main theme of this chapter, which, after a brief review and appraisal of the world oil and energy situation and outlook, formulates and applies a (hypothetical) crude oil production policy for the Arab world. The policy is based on the area's long-range interests and how it perceives those interests with respect to reconciling the objectives of resource conservation and current financial development needs. As a result, future magnitudes of the crude petroleum production variable (PCP) appearing in the energy balance model presented in Table 3.1 are estimated.

THE SITUATION

A great number of oil and energy projections have been published in recent years, mostly originating in the Western world (see Appendix 10). Although the conclusions of these studies have ranged widely, they can be broadly classified in three categories, according to the period when they were prepared: the aftermath of the Arab oil embargo and price increases of 1973–1974, the period 1976–1978, and the aftermath of the Iranian revolution.

After the Arab Oil Embargo

The projections in this category came as a reaction to the oil embargo and the price rises of 1973–1974 and, therefore, were mainly concerned with prices and security of supplies. The reality of the price increases was not taken for granted. Scenarios assuming alternative price levels were examined with a view to maintaining unchanged the future economic growth rates that had been forecast in the Western economies prior to the price rises. Oil demand was projected to be quite elastic to price changes. Investment in energy conservation and in the development of alternative energy sources was anticipated to respond almost immediately to higher oil prices. Vigorous government policies were expected to be enforced to curb the demand for oil. The idea was to break OPEC prices through considerably reduced oil import demand. The IEA was created. The USA undertook to achieve oil independence by 1985.

1976–1978

The projections in the second category were prepared in a completely different atmosphere. In the wake of the recession the Western world had realized that it would take much more time than was anticipated in 1974 to shift away from oil as the major fuel. The low rate of implementation of energy conservation measures in major consuming countries, delays and downward revisions in nuclear programmes, and slow progress in the development of other energy alternatives, led OECD governments to accept the dependence of their economies on OPEC oil as a real and long-lasting phenomenon. In the USA the Library of Congress published a "Project Interdependence" three years after the Administration's "Project Independence." The idea of breaking OPEC prices through reduced oil imports had, therefore, to be abandoned in a new world context of major concern by the OECD about lower economic growth perspectives for the rest of the century. Accordingly, the projections in this category generally examined scenarios assuming alternative rates of growth, which was not the case for the first category.

After the Iranian Revolution

The projections in the third category have been slow in coming, mainly because of the uncertainty of the new international oil situation created by the cutbacks in Iranian production and the resultant large increases in oil prices. Unlike the price rises of 1973–1974 when there was no near-term oil supply problem apart from the temporary reduction under the selective embargo, the price rises of 1979–1980 were mainly the consequence of a tight market. This tightness of oil supply, furthermore, may not be of a temporary nature, for a number of reasons related to conservationist production policies in many major producing countries, to technical limitations to production in others, and to the slow development of alternative energy sources. Thus, the projections in the third category are being performed in a climate of uncertainty about future oil prices *and* supplies. Accordingly, they have been examining scenarios making alternative assumptions about both price levels and economic growth rates.

After this brief overview of "Western projections," it must be added that these studies generally reflected the viewpoint and biases of the oil company, the government agency, the intergovernmental organization, or the academic group that sponsored or performed them at the particular time when they were being prepared. It has even been argued that they contributed in their own way to the decline in real oil prices before 1979.

In fact, the unprecedented inflation rates witnessed since 1974, the continued depreciation of the dollar (the oil payments currency), the soft oil market resulting from slow growth in the Western world[1] coupled with new non-OPEC supplies, and a virtual freeze on OPEC prices (21 percent nominal increase in almost five years), led to a substantial fall in the real price of oil and a considerable erosion of OPEC financial surpluses. This greatly helped the Western economies in absorbing the price rises of 1973–1974. The projections in the second category generally predicted a world oil shortage some time in the 1980s, once new non-OPEC supplies (mainly from Alaska, the North Sea, and Mexico) would have been absorbed into the world energy system. This much-publicized warning carried the often-explicit message for the producers that significant real price increases would be coming anyway through market forces with the advent of the shortage, so that there was no compelling need for oil price indexation in the meantime. "The widespread acceptance of the numerous studies predicting a supply-demand crunch in the next decade has put the question into a political rather than economic context in the consuming countries, and created a relaxed state of mind among the producers, as is witnessed by the dropping of their demand for the indexation of oil prices, on the grounds that the coming oil shortage will in any case increase prices faster than the world inflation rate."[2] It was not surprising, therefore, that while early projections in this category predicted a shortage as soon as the early to mid-1980s, subsequent studies or reassessments within the same category were pushing further into the future the date of the expected shortage.

Yet, a number of prominent geologists, engineers, and economists have declared on several occasions, individually or collectively, that, contrary to the forecasters' warnings of a coming shortage, the oil era was not about to end. This

[1] Economic growth in the OECD area averaged 2.5 percent per annum between 1973 and 1978, as against 5 percent between 1962 and 1973. The corresponding rates for net oil imports were about nil and 11 percent, respectively [6, 4].

[2] Fadhil Al-Chalabi, Deputy Secretary-General of OPEC [7].

conviction was best reflected in the conclusion reached by some 90 international energy experts gathered at the UNITAR/IIASA Conference on the Future Supply of Nature-made Oil and Gas [1], to the effect that "there is no dearth of petroleum and natural gas resources remaining in the earth. As a matter of fact, there is no foreseen shortage of available supplies by present technology until well into the next century.... Additional petroleum and gas resources would most probably be available albeit at a substantially higher cost not only for the next two or three decades but very likely during the period of transition to the use of renewable energy sources even if this transition period should last a hundred years or more."

Some reconciliation between such apparently contradictory findings may be achieved through the price variable. The projections predicting a shortage generally assumed that price would not change much in real terms, thus depriving this variable from its role of supply-demand regulator. On the demand side, higher prices may lead to better efficiency in oil usage and to more fuel switching away from oil in a number of sectors. On the supply side, more importantly, higher prices may lead to greater increases in proved reserves[3] and may justify production from higher-cost sources. From an economic point of view, therefore, the last barrel to produce, or marginal barrel, is also the most expensive. This mechanism, however, did not apply in the real world, and the marginal barrel came from the cheapest source, namely, the Middle East, which had to take virtually the whole of the swing in demand after assigning full outlet to all other sources of energy at a given price. That is why the approach taken by most projections in the second category ended up with the question whether, at a given price, Saudi Arabia would be willing to produce the residual amount required to fill the prospective supply-demand gap.

The problem of future oil supplies, therefore, is not so much a question of available resources as it is a question of the right price to develop these resources. Hence, the message is not that the end of the oil era is in sight; it is, rather, the relatively low-priced oil era which is ending.

The first signals came with the price increases of 1973–1974, but they were misunderstood or ignored because the subsequent gradual decline in the real price of oil in many countries, particularly in those whose currencies appreciated against the dollar[4], led governments of consuming countries to relax their efforts to implement more effective energy policies. It only took the events in Iran and the suspension of Iran's oil exports from late December 1978 to early March 1979 to change abruptly the relatively easy oil supply situation that prevailed in 1978 and to set off a new massive rise in oil prices.

With world supplies suddenly cut down by some 5 Mb/d at a time of high seasonal demand, attention focused on the spot market, where some 10–20 percent of oil traded internationally was bought and sold, as against 3–5 percent in normal times. And, indeed, prices on that market (which is not in any one location, but a worldwide network of telephone calls, traders, tankers, refineries, and storage facilities) have led to the general upward pull in official prices. Even the ability of Saudi Arabia to use its output flexibility to exert a tempering influence on prices became somewhat hampered by the fact that the Kingdom, in order to ease the pressure on oil markets, raised its production to levels (10.4 Mb/d in December 1978) close to sustained capacity.

Prices continued to rise after the resumption of Iranian oil exports in March 1979. This was due to the tightness of the market, where supply remained short of demand by an average of 2 Mb/d throughout 1979. As a result, official OPEC prices wound up at an average of about \$29/b at the beginning of 1980, as against a target of less than \$16/b for the end of 1979, which OPEC had aimed at in its December 1978 meeting in Abu Dhabi.[5]

[3] Proved reserves refer to oil that is recoverable from known reserves with present prices and technology. Thus, additional oil resources that are not recoverable with today's prices may become part of proved reserves when prices rise.

[4] Reasons for that price decline were outlined on four paragraphs above.

[5] The OPEC prices mentioned here are weighted averages, the weights being individual OPEC member country production volumes. The corresponding prices for the "marker" crude are \$26/b and \$14.54/b, respectively.

The Iranian crisis has demonstrated the large impact that a small decline in oil supply availabilities–2 Mb/d out of a total world production of 63 Mb/d, i.e., 3 percent–can have on oil prices. "There are important lessons here. The solution to the energy problem rests essentially on allowing the price mechanism to play its traditional role in shifting demand and supply away from oil. But the nature of the energy and oil market is such that market forces cannot simply be left to themselves.... Because of the long lead times and sheer size of the investments required, there is a clear need for government measures, as a supplement to market forces, to promote investment in energy saving and indigenous production....It is therefore important for the market to be managed in such a way that, whatever is happening to the short-term supply and demand situation, consumers and producers of energy see clearly that over time the real price of oil is going to rise steadily, up to the cost of alternatives....Events in 1979 underlined only too clearly the need for cooperative action at international level....It is going to take a great effort of political will, both nationally and internationally, to ensure that demand for OPEC oil does not exceed available supplies."[6]

The following main points emerge from the above analysis:

1. Most of the oil and energy projections published since 1974 have so far reflected the viewpoint of the consumers.
2. The tight oil market that prevailed in 1979 has created a climate of uncertainty about oil supplies that may well continue in the future.
3. There is a clear need for cooperative action at the international level to ensure that future oil demand does not exceed available supplies.

All three points underline the necessity of a well defined, long-term production strategy for the producers. First, it would be difficult for any serious "Western projection" exercise to ignore a clearly and collectively spelled out producers' viewpoint, which would render the exercise more objective and, hence, more useful in mapping energy futures. Second, a producers' strategy would clearly show the extent of the conservationist production policies in major exporting countries and would, thus, lift the uncertainty now prevailing about future oil supplies. Third, the strategy would provide a basis for a much needed concerted action between producers and consumers, allowing the latter to initiate the long-term adjustments in their economies necessary to ensure that future oil demand would not exceed available supplies.

The Arab world plays and will continue to play a key role on the international oil scene. Arab countries account for some 60 percent of total world crude oil exports and meet about two-thirds of the net crude import needs of the OECD area. A well defined, clearly spelled out Arab long-term crude oil production policy would, therefore, constitute a factor of prime importance in lifting the uncertainty about future world oil supply availabilities and, hence, assisting the oil important countries in their efforts to adjust their economies on a durable basis to the future oil and energy situation.

AN ARAB LONG-TERM CRUDE OIL PRODUCTION POLICY

Any sound crude oil production policy for the Arab world has to be based on the area's long-range interests and how it perceives those interests with respect to reconciling the objectives of resource conservation and current financial development needs. The prime concern of this developing region, in the face of rapidly growing demand for its depletable oil resources, is that these resources should last as long as it would need them. In more explicit terms, oil should continue to provide the fuel, raw material, and foreign exchange required for a rapid and balanced development and diversification of the Arab economies, and it must continue to provide until it can be replaced by alternatives that would be available (with appropriate technologies) at competitive prices and in sufficient quantities. With the present state of development of alternative energy sources and their prospects as seen today, it is widely recognized that these will not play an important

[6] Emile van Lennep, Secretary-General of OECD [8].

role in the energy balance of the industrialized world before the turn of the century. As to when appropriate new technologies would be available and well established on a sufficiently large scale in the Arab world so as to make substantial contributions to the Arab energy balance, the future is even more uncertain and the lead times much longer. When that time comes, renewable sources such as solar energy, nuclear power, wind energy, biomass conversion, and geothermal energy—together with the plentiful resources of unassociated natural gas that are estimated to exist in a number of Arab countries—would constitute the new oil alternative energy resource base for the Arab world. But even then oil would have to continue to be used as raw material for nonenergy purposes.

In view of the above, one of the prime concerns of an Arab long-term crude oil production policy should be resource conservation. It is assumed here that an aggregate reserves to production (R/P) ratio of 20 to 1 is the minimum that the Arab world as a whole would envisage today for a long period of time into the future. This 20 to 1 lower limit, being an Arab average, would, of course, conceal upward and (especially) downward variations in the R/P ratios of individual countries, depending on their respective contributions to aggregate output. Some of the countries with a ratio below the 20 to 1 average would even be getting close to their "technical limit," beyond which it would be impossible for them to continue to produce without reducing the amount of crude that could be eventually recovered.[7] It is noteworthy that in 1979, for example, the R/P ratio of each of Algeria, Bahrain, Egypt, Morocco, Dubai, and Sharjah was already below 20 to 1.

The chief prerequisite for the formulation of a sound production policy is an accurate assessment of Arab recoverable oil resources. This includes, for any one year, the level of proved reserves as well as future gross additions to proved reserves. It is essential that such an assessment be undertaken by an independent body, preferably a pan-Arab organization specially established for that purpose. This is because the estimation of proved reserves that has so far been generally undertaken in the Western world may not have been completely objective at times nor sufficiently documented. These factors have resulted in published estimates of Arab proved reserves sometimes ranging widely from one source to another or incurring substantial revisions from one year to another.[8] The Arab body to be entrusted with this task would, of course, have to have access to all relevant national information in order to effectively fulfil its mandate. It would carry out its estimation work on a recurrent basis, in the sense that the estimates of the level of proved reserves and future gross additions to reserves would remain under constant scrutiny and would undergo continuous updating in the light of newly acquired knowledge. Results would be made public on a regular basis, say every other December, and preferably for the Arab world as a whole.

For the sake of illustration, and in order to highlight some of the problems involved in this task, an independent specialist was commissioned by ECWA to assist the author of this book in the estimation of the level of proved reserves and of future gross additions to reserves. The methodology used by the consultant and his findings are reported in Appendix 7. The exercise had to be limited by tight time and budgetary constraints, but it gives a sketchy illustration of what the independent inter-Arab estimation work described above could be.

The main variable in the exercise undertaken in Appendix 7 is what the American Petroleum Institute calls the "current estimate of ultimate recovery" (also called by King Hubbert "cumulative proved discoveries"), which is actually equal, for any one year, to the sum of proved reserves and cumulative production up to the end of that year. Appendix 7 estimates the value of this variable for each year in the 1977-2001 period and also attempts a projection of ultimate recoverable resources. In addition

[7] The world average for this "technical" R/P limit is estimated at 10 to 1 [2].

[8] For example, *Oil and Gas Journal* and *World Oil* estimates of Arab proved reserves at the beginning of 1978 differed by some 45 billion barrels (Bb). *Oil and Gas Journal* revised downwards at the beginning of 1974 its estimate of Arab proved reserves published one year earlier by 45 Bb. (Arab crude production in 1973 amounted to 6.8 Bb.) See Appendix 3.

Table 4.1

Current Estimate of Ultimate Recovery[a], Ultimate Recoverable Resources, and Gross Additions to Proved Reserves in the Arab World, 1977-2000 (Bb).

	End of Year										Ultimate Recoverable Resources
	1977	1978	1979	1980	1984	1985	1989	1990	1999	2000	
1. Arab Middle East	410.00	416.59	422.80	428.65	448.81	453.12	467.84	470.96	491.41	493.00	514.5
Saudi Arabia[b]	194.35	197.40	200.30	203.00	212.32	214.31	221.12	222.57	232.49	232.77	242.7
Kuwait[b]	96.25	96.25	96.25	96.25	96.25	96.25	96.25	96.25	96.25	96.25	96.3
Iraq	55.20	56.85	58.41	59.90	65.10	66.23	70.13	70.97	76.55	76.99	83.1
UAE	47.70	49.12	50.48	51.76	56.25	57.23	60.60	61.32	66.14	66.53	71.8
2. North Africa	55.50	57.36	59.14	60.82	66.74	68.03	72.50	73.46	79.87	80.38	87.5
LAJ	35.60	36.79	37.93	39.01	42.81	43.63	46.50	47.12	51.23	51.56	56.1
Algeria	15.20	15.60	15.90	16.25	17.40	17.65	18.51	18.69	19.90	20.00	23.1
3. Arab World (1+2)	465.50	473.95	481.94	489.47	515.55	521.15	540.34	544.42	571.28	573.38	602.0
4. Gross Additions to Arab Reserves[c]		8.45	7.99	7.53	5.94	5.60	4.35	4.08	2.25	2.10	
5. Cumulative Gross Additions to Arab Reserves After 1977		8.45	16.44	23.97	50.05	55.65	74.84	78.92	105.78	107.88	136.5

[a]The current estimate of ultimate recovery is defined as the sum of cumulative production to date and the current estimate of proved reserves.
[b]Including country's share of the Neutral Zone.
[c]Gross additions to proved reserves are equal, for any one year, to the difference between the values of the current estimate of ultimate recovery at the end of that year and at the end of the previous year.
Source: Appendix 7.

to the Arab world, which is broken down into countries or groups of countries, Iran is also covered.

The quantitative findings of Appendix 7 for the Arab world are summarized in Table 4.1 for selected years. As shown under item 4 of the table, estimates of gross additions to Arab proved reserves are derived, for any one year, as the difference between the values of the current estimate of ultimate recovery at the end of that year and at the end of the previous year.

Table 4.1 gives a 1977 estimate of ultimate recovery in the Arab world equal to 465.5 Bb.[9] Deducting from this the amount of Arab cumulative crude production up to the end of 1977 (92.4 Bb—see Table A3.2), Arab proved reserves at the end of 1977 (or at the beginning of 1978), thus, come to 373.1 Bb. This study's estimates of the level of Arab proved reserves is, therefore, about 10 percent higher than that of the *Oil and Gas Journal* (340.5 Bb. at the beginning of 1978—see Table A3.1). On the other hand, however, this study's estimates of Arab ultimate recoverable resources (602 Bb) and, hence, of future gross additions to Arab proved reserves (a total of 136.5 Bb after 1977), are believed to be on the conservative side. They probably underestimate the size of new discoveries in countries like Saudi Arabia, the UAE, and, above all, Iraq—where ultimate recoverable resources could be as high as 255, 90, and 125 Bb, respectively. Moreover, they do not take full account of the future contribution of small fields (where production costs are at present much higher than those of the giant prolific fields of the area), which have so far been neglected as noncommercial. They, finally, underestimate the recovery factor in some important Arab reservoirs, which could actually turn out to be quite high (see Appendix 7, pp. 166-167). For all these reasons, Arab ultimate recoverable resources might well be in the neighbourhood of 680 Bb, which implies that cumulative gross additions

[9] 1977 is the base year of the estimation work undertaken in Appendix 7.

to Arab proved reserves after 1977 might well be 55 to 60 percent above this study's estimates (about 215 Bb instead of 136.5 Bb).

The next step in the formulation of an Arab crude oil production policy is to choose the base year and to decide on the aggregate output of that base year. In the present exercise the base year is chosen to be 1980. As for the Arab output for 1980, it has to be set by policy decision. In 1979 Arab crude production rose by more than 12 percent to an all-time record of 8.06 Bb (22.1 Mb/d). The reason for that spectacular increase was to compensate for the reduction in Iranian output (down 2.2 Mb/d from 1978, or 41 percent—see Table A3.2). In fact, the combined production of the Arab world and Iran was in 1979 estimated at 9.19 Bb (25.2 Mb/d), which is only 1 percent above its level of 1978 (9.10 Bb or 24.9 Mb/d). Moreover, certain major Arab producers (like Saudi Arabia and Kuwait) made it clear that the increments in their output witnessed in 1979 were of a temporary nature and that they should not be expected to continue to produce above established ceilings. There is, therefore, reason to believe that Arab crude production in 1980 may be below that of 1979. The (hypothetical) policy decision adopted here is to set for 1980 the average R/P ratio for the Arab world in such a manner as to ensure that aggregate output will be the closest possible to, but higher than the average of, the 1977, 1978, and 1979 production levels (7.55 Bb or 20.7 Mb/d—see Table A3.2). Using this study's estimate for Arab reserves at the beginning of 1980 (374.34 Bb, from Table 4.1 and Table A3.2), the average Arab R/P ratio for 1980 is, thus, set at 49 to 1, leading to an Arab output of 7.64 Bb (20.9 Mb/d).

Appendix 6 presents two hypothetical Arab crude oil production policy models and their application, on the basis of the above findings, between the base year and the year when the R/P ratio reaches 20 to 1.

Model 1

Model 1 assumes that the average Arab R/P ratio would be allowed to decrease by one point every year. Starting with 49 to 1 in 1980 (see above), it would be set at 48 to 1 in 1981, 47 to 1 in 1982, and so on. This would continue until the year when the R/P ratio would reach the 20 to 1 limit (in 2009), beyond which it would be maintained at that level. Thus, production would be determined as one-forty-eighth of reserves in 1981, one-forty-seventh of reserves in 1982, and so on until 2008, when it would be determined as one-twenty-first of reserves. Thereafter, output would be maintained at 5 percent (one-twentieth) of reserves. The application of Model 1, based on the illustrative findings of Appendix 7, is shown year by year up to 2025 in Table A6.1.

In case Model 1 was adopted as the basic framework for the Arab long-term production policy, and bearing in mind that the pan-Arab organization entrusted with the task of estimating the level of Arab proved reserves and future gross reserves additions would be updating those estimates every other December (see p. 37), the future Arab production profile as derived from the application of the model at the beginning of 1980 would be revised at the beginning of 1982 in light of knowledge acquired in 1980 and 1981, and so on. The 1980 estimation work would, of course, determine future Arab output for all years, but the estimation of Arab proved reserves at the beginning of 1980 and of gross reserves additions accruing in 1980, in particular, would be of prime importance since these would determine the 1980 and 1981 production levels once and for all. The determination of output in subsequent years would only be a first approximation to be reassessed in future biennial exercises. The 1982 estimation work would likewise determine the 1982 and 1983 production levels once and for all, while the determination of subsequent annual output levels would only be indicative, to be reassessed in future biennial exercises. Consequently, the 1980 estimation of the future production profile (an illustration of which is shown in Table A6.1) would only commit the Arabs for their aggregate output in 1980 and 1981, while the outputs for subsequent years as determined by the model would only be indicative. Similarly, the 1982 estimation of the future production profile would only commit the Arabs for their aggregate output in 1982 and 1983, and so on.

Model 2

Model 2 assumes that Arab crude oil production would be increasing by 2 percent per annum between 1980 and 1990,,by 1 percent between 1990 and 2000, and would be maintained at the same level (reached in 2000) throughout a period extending from the turn of the century to the year when the R/P ratio would reach 20 to 1, beyond which production would be determined as 5 percent (one-twentieth) of reserves. The application of Model 2, based on the illustrative findings of Appendix 7, is shown year by year up to 2025 in Table 6.2. The table indicates that the R/P ratio would reach the 20 to 1 limit in 2009, too. Had that R/P lower limit been reached before 2000, the model would have been adjusted accordingly (see Appendix 6, p. 161).

In case Model 2 was adopted as the basic framework for the Arab long-term production policy, the biennial updatings of the estimates of Arab proved reserves and gross reserves additions might have an effect on the year when the R/P ratio would reach the 20 to 1 limit, bringing it forward in case of downward revisions in the level of reserves and/or gross additions, or pushing it further into the future in case of upward revisions.

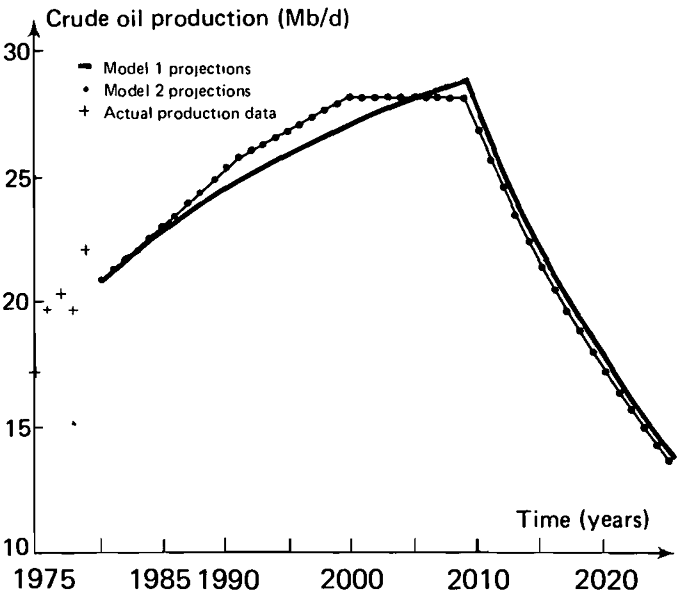

Figure 4.1. Illustrative application of two Arab crude oil production policy models.

The results of the illustrative application of Models 1 and 2 are represented in graphical form in Figure 4.1.

In this study Model 2 has been preferred to Model 1 and adopted as *the* Arab long-term crude oil production policy model. The reason for that choice is twofold: 1) Model 2 contributes better than Model 1 to lifting the uncertainty about future Arab oil supplies, in the sense that the biennial updatings mentioned above would be likely to have a greater influence on the future Arab production profile as derived from Model 1. Under Model 2 the annual growth rate of Arab output would be known for a longer period of time. 2) Arab cumulative output during 1980-2005 would be greater by 5.5 Bb under Model 2 than under Model 1,[10] which would contribute a little more to easing the pressure on world oil supplies in the coming 25 years.

For the purposes of the present study, therefore, Arab crude oil production is projected (using Model 2) as shown in Table 4.2.

It may be interesting to compare projected output to anticipated sustainable productive capacity in the Arab world. On the basis of the findings of Fransisco Parra,[11] it is estimated that Arab crude oil sustainable productive capacity would increase by 0.3–0.4 Mb/d per annum between 1980 and 1990 and by 0.2–0.3 Mb/d per annum between 1990 and 2000. Thus, future production would compare to capacity as shown in Table 4.3.

A last remark bears upon the distribution of total Arab output among individual producing countries. This chapter has so far dealt with the Arab world as a whole, and the long-term production policy described above has yielded a future Arab crude oil production profile in aggregate. In reality, agreement on an aggregate output target cannot be reached without a broad understanding on individual country contributions to that output. For the Arab production policy to be implemented in an effective and durable manner, it is essential that national interests be safeguarded. For instance, countries with large populations, ambitious devel-

[10] Greater by 4.6 Bb (2.5 percent) during the time span covered by this study (1980-2000).

[11] Presented at the Tenth World Petroleum Congress (September 1979)[9].

Table 4.2

Projection of Arab Crude Oil Production, 1980-2010.

	1980	1985	1990	1995	2000	2005	2010
In Bb	7.64	8.44	9.31	9.79	10.29	10.29	9.79
In Mb/d	20.9	23.1	25.5	26.8	28.2	28.2	26.8
PCP (in Mtoe)[a]	1,061.4	1,172.5	1,295	1,361	1,431	1,431	1,361 (1)[b]

[a]The conversion from Mb/d into Mtoe is based on an average Arab crude petroleum specific gravity, computed for each year as the weighted average of individual country specific gravities, the weights being the projected approximate contributions of each country to aggregate output (see Appendix 9).

[b]The number in parentheses refers to the corresponding step in the sequence of the projections as shown in Chapter 3 (p. 27).

Table 4.3

Future Arab Crude Oil Production Compared to Capacity, 1980-2000 (Mb/d).

	1980	1985	1990	1995	2000
Arab Sustainable Productive Capacity	25.6	27.4	29.2	30.5	31.7
Arab Production	20.9	23.1	25.5	26.8	28.2
Excess Sustainable Capacity	4.7	4.3	3.7	3.7	3.5

opment programmes, and/or financial deficits may need to produce near capacity, while others may have conservationist production policies. The target output should, therefore, be apportioned among individual countries with due regard to their national goals and aspirations.

OPEC has so far been leaving decisions on production levels to individual member countries, and an OPEC coordinated production programme is not likely to be introduced in the near future. It is worth noting to this effect that the report of the Group of Experts of the OPEC Ministerial Committee on Long-Term Strategies, which was to be presented subsequently to an OPEC summit meeting for adoption, concentrated on pricing issues and relations with developing and developed countries rather than on production programming.

This is yet another reason why it is important that the Arabs should succeed in this endeavour. Furthermore, the Arab world represents a much more homogenous entity than the group of countries forming OPEC. Finally, within a context of common geographical, human, political, and economic motivations and aspirations, Saudi Arabia would probably show more willingness to play the role of swing producer so as to ensure to the Arab production programme the internal flexibility necessary for its successful implementation.

FIVE
PETROLEUM PRODUCTS

The previous chapter was confined to the projection of one of the 15 oil variables in the energy balance model, namely, the Arab world's future production of crude petroleum (PCP), because of its paramount importance to the future world oil and energy situation. The present chapter is concerned with the 14 remaining oil variables in the model. More precisely, six exogenous petroleum products variables are estimated here (CPP, REF, RCP, RNG, REL, and BNK). They serve to determine future values of five endogenous oil variables (TPP, TCP, XCP, R, and XPP) using the first five model structural identities (see p. 27). The projection of yet another three exogenous variables (PGL, ECP, and EPP), which will be undertaken in Chapters 6 and 7, is also reported in this chapter because they are necessary for the estimation of most of the other 11 oil variables.

PRODUCT CONSUMPTION

Gross final consumption of petroleum products in the Arab world (CPP) is determined here as a function of Arab gross domestic proɹuct (GDP). This is justified by the fact that pətroleum products are used in one form or another in the great majority of productive activities in the economy, and GDP is one of the best measures of the level of economic activity.

The relationship between CPP and GDP is estimated on the basis of historical data, using the following simple econometric model which is then tested for forecasting suitability:

(E1) $$CPP = c_1 + c_2 . GDP.$$

CPP historical data are taken from the energy balances of the Arab world for the years 1960 to 1978, compiled in Appendix 1 (Table A1.2) as the sum of the figures in absolute terms of rows 9 and 10 in column 3. This is because variable CPP in the energy balance model (see Table 3.1) includes all domestically consumed NGL, unlike the corresponding item in Appendix 1 (row 10, column 3), which excludes NGL entering refineries (see pp. 27 and 105).

Since CPP historical data are expressed in Mtoe, i.e., in physical terms, they have to be coupled with GDP data also expressed in physical (real) terms, i.e., valued at the prices of a given base year. Moreover, a regional relationship is considered here, i.e., Arab CPP as a function of Arab GDP. Thus, the latter will have to be a summation of individual country GDP data valued at the prices of the same base year and expressed in the same currency at the exchange rate of that base year.

ECWA's Statistics Unit has compiled, for the purposes of this study, historical estimates of the real GDP of each of the 21 Arab countries, expressed at constant prices of 1970 and in million US dollars of 1970 [10]. The results of this work are summarized in Appendix 8, where Table A8.2 presents estimates of the aggregate real GDP of the Arab world for the years 1960 to 1977.

Based on the above historical data, the following econometric relationship is derived:

$$CPP = -11.33 + 1.0206\ GDP\ (\bar{R}^2 = 0.95),$$

where CPP is in Mtoe, GDP is in billion 1970 dollars at 1970 prices, and $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom associated with the regression.

While the high value of $\bar{R}^2$ reflects the goodness of the historical fit, the opposite algebraic signs of the two regression coefficients are an indication of its suitability for forecasting purposes. This is because the GDP elasticity of CPP implied in the regression is a decreasing function of GDP[1]. In other terms, as GDP grows in time, the growth rate of CPP increases at a slower pace than the growth rate of GDP. This is realistic for a region that is in rapid development and where alternatives to oil products (mainly natural gas and electricity) are expected to be made available in increasing quantities for final consumption.

Accordingly, the coefficients of equation (El) are estimated as follows for the years 1985, 1990, and 2000, respectively:

c_1 (in Mtoe)	-11.33	-11.33	-11.33
c_2	1.0206	1.0206	1.0206

PRIMARY REFINING

An Arab Long-term Refining Policy

This study assumes that, as a matter of policy, future Arab refinery output would comprise the following components:

1. The amount of refined products necessary to meet Arab demand, inclusive of bunkers.

2. An additional percentage of the amount in 1. above, as a result of the surplus in certain products (e.g., heavy distillates) that would inevitably emerge in meeting demand for other products, and also as a result of modest product exports in a few cases.

3. A certain amount of exportable refinery feedstock produced from heavy, sour crude in specialized Arab refineries.

4. A certain amount of products refined on commission in some non-Arab consumption centres.

Justification of this assumption is provided below.

Many plans to build "export" refineries (i.e., large plants producing petroleum distillates essentially for export) have been announced in the Arab world since 1974. In the event that all such plans were to be executed, Arab primary refining capacity would have been pushed to over 10 Mb/sd by 1985. As it happens, a number of projects have been abandoned or delayed, and an analysis of current programmes implies that a maximum of 5 Mb/sd would be added during the 1980s to Arab capacity, which stood at around 3.3 Mb/cd by mid-1980 (or about 4 percent of world capacity).

A recent ECWA study [11] has challenged the economics of export refineries, arguing that such ventures have the perverse consequence of turning crude oil which is cheap to transport (in large "dirty" tankers) into products that are expensive to transport (in small "clean" tankers). This is quite apart from the fact that the existing excess capacity of crude carriers, which means that they can be hired at anomalously low freight rates, may well continue in the future, particularly if the amount of crude to be carried ceased to rise as a result of increased refining and conservationist crude production policies in the main exporting countries. Besides, the substantial surplus refining capacity existing in all areas outside the USA and Japan has narrowed refinery margins and led to difficulties in marketing certain products, even at cut prices, and this trend is likely to continue in the future [12]. Moreover, an oil exporting coun-

[1] $CPP = c_1 + c_2.GDP$

$$E = \frac{c_2.GDP}{c_1 + c_2.GDP}$$

$$E' = \frac{c_1 \cdot c_2}{(c_1 + c_2.GDP)^2},$$

where E is the GDP elasticity of CPP and E′ its derivative relative to GDP. E′ is negative, i.e., E is a decreasing function of GDP, if and only if the product $c_1 \cdot c_2$ is negative.

try that built an export refinery might well be able to overcome these problems (and show a profit in the refinery) either by supplying it with cut-price crude or by using "leverage" to force the oil companies to take the products at uneconomic prices as a condition of being guaranteed a certain amount of crude at official prices. In both cases, however, the profitability of the export refinery would be the result of a subsidy, given directly in the former case, but hidden in the latter since "leverage" could have otherwise been used for other more economically useful purposes. Finally, export refineries, as assessed in relation to alternative development projects, are capital-intensive, have a long gestation period, require a large outlay of foreign exchange for establishment, put a strain on the construction industry and on the government machine (which are normally over-stretched in rapidly developing economies due to limited absorptive capacity), generate a relatively small value added of which an unusually large proportion represents depreciation (which is not part of national income), add little or nothing to the net earnings of foreign exchange that could have been obtained by exporting the crude oil, require a high proportion of skilled and professional workers, and have little in the way of useful linkages with the rest of the economy, either during the construction phase or when the refinery is in operation.

The ECWA study concludes that it is "clearly advantageous for refineries to be built on a scale at least sufficient to keep pace with the expected growth of regional demands for refined products."

In more explicit terms, refineries would be so designed as to primarily meet Arab demands for products but would generate a surplus for two reasons. First, the output mix cannot be expected to match the consumption mix at all exactly. Thus, there would have to be regular surpluses in certain products to ensure an adequate supply of each separate product. Such surpluses would have to be exported, but they are anticipated to gradually decline in relative terms with the emergence of new, more sophisticated refineries and the reconversion of some existing ones, which would bring the overall output mix more in line with the Arab consumption pattern. Second, patterns of product demand are not the same in all areas of the world, so that some international trade in specific products is needed to bring supply and demand into balance everywhere. This makes it advantageous to have a limited surplus capacity in a central position (e.g., the Gulf) that can supply some products to major consuming areas that are far apart (e.g., Europe and Japan).

On the other hand, a paper presented at the Tenth World Petroleum Congress in September 1979 [12] has projected that future oil demand growth in the major consuming areas would be largely for lighter, sweeter products, at a time when supply increases would be predominantly in heavier, sour crude oils, particularly in OPEC countries.[2] Meeting these expected changes in product demand patterns and quality specifications presupposes the supply of adequate quantities of suitable crude oils and the requisite refinery upgrading and conversion capacity. One way of solving the problem would be to take the opportunity of the refining developments in producing countries to convert heavy (low-API gravity), sour (high-sulphur) crude oil into lighter (higher-gravity), sweeter (lower-sulphur) "reconstituted" crude for export, making use of the availability of associated flare gas for an energy-intensive hydrocracking process.

There would be definite advantages in performing such conversion operations in Arab oil-producing countries. First, the conversion cost, as estimated by the paper, seems to be well below the current value differential between the corresponding input and output crudes. The producer would, thus, benefit from the "uplift" of this operation, which would be particularly profitable in the Arab world, where heavy crude oils are expected to have an increasing share in the crude output mix and where important quantities of associated gas (to be used as feedstock in the conversion process and also as fuel) are still being flared. Second, this activity would help integrating the growing capacity in Arab countries into the world refining system at a time of worldwide surplus capacity. Third, it

[2] In the case of Saudi Arabia, the paper has estimated that the share of Arabian Light in total crude output would decline from 72 percent in 1977 to 50 percent in 1985.

would relieve the producer of the problem of marketing finished products. Fourth, the reconstituted crude could still be transported in large crude carriers. And fifth, the output crude could be "tailor-made," possibly seasonally varied, for the marketing needs of refineries in the consuming areas.

The supply of reconstituted crude oil is not a new development. It has taken place in the past but mainly within the integrated channels of the major international oil companies or under long-term contractual arrangements between suppliers and individual refiners. It is not suitable for short-term operations, but it could form the basis for forging long-term relationships between producer and consumer country refineries, giving the former a share in the "uplift" and providing the latter with a durable supply of suitable crude oil.

Finally, Arab producers have recently been making use of the excess capacity in some European refineries to run a certain amount of crude for a fee and sell the finished products on nearby markets. This operation is clearly advantageous because substantial savings are made by transporting crude to the consuming areas instead of products refined at home (see p. 44). Moreover, refineries near the markets normally yield a product mix more in line with the consumption pattern than the output mix of producer country refineries, and this helps greatly in marketing the various products. All in all, the activity appears to be quite profitable, provided that surplus capacity near the consuming markets remains available, and this is likely to continue to be the case in all areas outside the USA and Japan.

In the light of the above, future Arab refinery output is assumed to be determined according to the following equation, using the notation of the energy balance model presented in Table 3.1.

(E2) REF = (1 + s) [CPP - g.PGL + EPP + BNK] + x.PCP,

where:

- g is the percentage of NGL production consumed in the Arab world;
- CPP - g.PGL + EPP + BNK is equal to total Arab requirements of refined products (component 1. of the assumption made on p. 44);
- s is the additional percentage of Arab requirements to be generated as exportable surplus in primary distillation units (component 2.);
- x is the percentage of Arab crude output to be exported either as reconstituted crude obtained from Arab specialized refineries (component 3.) or as products refined in non Arab consumption centres (component 4.).

Future magnitudes of the three parameters included in equation (E2) are estimated as follows:

1. For parameter g, on the basis of programmes and perspectives of individual Arab producing countries in the NGL field (see p. 49).

2. For parameter s, under certain assumptions concerning the future Arab refinery mix, the evolution of product consumption patterns and the prospects for the export of some products (mainly from Bahrain, Kuwait, and Saudi Arabia to Japan).

3. For parameter x, on the basis of an assumed policy for the export of increasing quantities of reconstituted crude from Arab specialized refineries and for the use of non-Arab refineries near the major markets to process a more-or-less fixed proportion of Arab crude output into finished products for sale.

Accordingly, the following percentages are derived for 1985, 1990, and 2000, respectively:

g	7.3	11.6	16.0
s	20	15	8
x	5	10	20

Refineries' Own Energy Use and Losses

Following the procedure used in Appendix 1 (see p. 111), refinery throughput and refineries' use of natural gas and of electricity are determined in direct proportion to refinery output:

(E3) $RCP = r_1.REF$
(E4) $RNG = r_2.REF$
(E5) $REL = r_3.REF.$

Future magnitudes of r_1, r_2, and r_3 are estimated on the basis of the following assumptions:

1. Crude throughput and energy use would increase gradually per unit of refinery output as a result of the emergence of more sophisticated refineries in the Arab world yielding a lighter product mix or transforming heavy, sour crude into a lighter, sweeter crude, and also as a result of the use of Western refineries on commission.

2. Natural gas use per unit of refinery output would, in addition, be influenced by two conflicting factors. On the one hand, the amount of crude refined outside the Arab world on commission would not call on Arab gas for processing. On the other hand, Arab specialized refineries producing reconstituted crude would require increasing quantities of natural gas as raw material.

Accordingly, the following percentages are derived for 1985, 1990, and 2000, respectively:

r_1	103.8	104.1	104.5
r_2	2.3	3.0	4.0
r_3	0.2	0.2	0.3

BUNKERS

Three types of petroleum products are mainly used in the Arab world to fuel aircraft and ships in international transportation, namely, aviation gasolene, jet fuels, and fuel oils.

Aviation gasolene is essentially used in piston-engine aircraft, which have been gradually disappearing in international transportation. The share of aviation gasolene in total Arab bunkers had dropped 17-fold by 1976–1978 from an already quite low 1.6 percent in 1960.[3] It is projected, therefore, that this component of Arab bunkers would be negligible in the future.

Jet fuels supplied to turbine-engine aircraft in international transportation have witnessed an impressive increase in the past two decades, reaching 11 percent of total Arab bunkers in 1977–1978 as against 1 percent in 1960. During the 1960–1974 period, Lebanon's share in the Arab world's jet fuel bunkering activities averaged more than 36 percent. Historical semilogarithmic regression trends indicate an average annual growth rate of 13.2 percent for Lebanon during that period ($\bar{R}^2 = 0.93$)[4] and a rate of 15.5 percent for the Arab world outside Lebanon over the 1960–1978 period ($\bar{R}^2 = 0.95$). The latter rate is projected to be maintained through 1985, except for Lebanon where the level of 1974 is assumed to be recovered by 1980 and the historical 1960–1974 rate is applied to 1985. Thereafter, total Arab jet fuel bunkers would grow at 10 percent per annum in the second half of the 1980s and at 7 percent during the 1990s. Accordingly, this type of Arab bunker is projected to reach 4.6 Mtoe in 1985, 7.4 Mtoe in 1990, and 14.6 Mtoe in 2000.

Fuel oils supplied to ships in international transportation represent the great majority of the Arab world's bunkering activities, although their share in the total declined from 97 percent during 1960–1967 to 89 percent in 1977–1978. In 1978 Saudi Arabia accounted for more than 69 percent of Arab marine bunkers, followed by Kuwait with less than 19 percent. The corresponding shares in 1972, when Kuwaiti oil exports reached their peak, were less than 62 percent and more than 21 percent, respectively. These two observations would imply that marine bunkers are mainly used in oil tankers and are, therefore, closely related to oil exports. Actually, the ratio of fuel oil bunkers to net oil exports in the Arab world has been fluctuating during the 1968–1978 period[5] around a mean of 2.2 percent with a standard deviation of 0.5 percent. Accordingly, future magnitudes of fuel oil bunkers are estimated at 2.2 percent of net Arab oil exports.

[3] All percentage shares in this section refer to heat values.

[4] $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom associated with the regression.

[5] The 1968-1978 performance has been selected as a basis for the projection of fuel oil bunkers because the pre-1968 period witnessed a different situation when the port of Aden (Democratic Yemen) averaged over one-quarter of the Arab world's ship-bunkering activities, as against an average of only 1 percent in the 1970s. This drastic reduction was due to the closure in 1967 of both an important British base in Democratic Yemen and the Suez Canal.

$$
\begin{bmatrix}
1 & & & & & & & & & & \\
-1-s & 1 & & & & & & & & -1-s & \\
-1 & 1 & 1 & & & & & & & & \\
 & -r_1 & & 1 & & & & & & & \\
 & & & -1 & 1 & & & & & & \\
 & & & & 1 & 1 & & & & & \\
 & -r_2 & & & & & 1 & & & & \\
 & -r_3 & & & & & & 1 & & & \\
 & 1 & & -1 & & & -1 & -1 & 1 & & \\
 & & & & & -b_2 & & & & 1 & -b_2 \\
 & & 1 & & & & & & & 1 & 1
\end{bmatrix}
\times
\begin{bmatrix}
CPP \\ REF \\ TPP \\ RCP \\ TCP \\ XCP \\ RNG \\ REL \\ R \\ BNK \\ XPP
\end{bmatrix}
=
\begin{bmatrix}
c_1 + c_2 .GDP \\ (1+s)\ (EPP-g.PGL)+x.PCP \\ EPP \\ 0 \\ ECP \\ PCP \\ 0 \\ 0 \\ 0 \\ b_1 \\ PGL
\end{bmatrix}
$$

which, in matrix notation, becomes:

$$A \cdot \vec{y} = \vec{a},$$

where A is an (11,11) matrix, $\vec{y}$ is the 11-vector of oil variables, and $\vec{a}$ is an 11-vector of exogenously determined components.

Figure 5.1. Matrix form of oil projection submodel.

In the light of the above considerations, Arab international bunkers are projected on the basis of the following formula:

(E6) $BNK = b_1 + b_2(XCP + XPP)$,

where b_1 and b_2 are estimated as follows for 1985, 1990, and 2000, respectively:

b_1 (in Mtoe)	4.6	7.4	14.6
b_2 (in percentage)	2.2	2.2	2.2

THE OIL PROJECTION SUBMODEL

The six equations (E1) to (E6) constructed in the preceding sections, together with the first five identity relationships inherent to the structure of the energy balance model presented in Table 3.1 (see p. 26), constitute a fully identified submodel that allows one to solve the 11 oil variables—CPP, REF, TPP, RCP, TCP, XCP, RNG, REL, R, BNK, and XPP—as functions of the variables PCP, GDP, PGL, ECP, and EPP, which are determined exogenously to the submodel.

The equations and identities of the oil projection submodel are listed below for easy reference:

(E1) $CPP = c_1 + c_2.GDP$

(E2) $REF = (1 + s)\ [CPP - g.PGL + EPP + BNK] + x.PCP$

(I1) $TPP = CPP - REF + EPP$

(E3) $RCP = r_1.REF$

(I2) $TCP = ECP + RCP$

(I3) $XCP = PCP - TCP$

(E4) $RNG = r_2.REF$

(E5) $REL = r_3.REF$

(I4) $R = RCP + RNG + REL - REF$

(E6) $BNK = b_1 + b_2\ (XCP + XPP)$

(I5) $XPP = PGL - TPP - BNK.$

The submodel can be written in matrix form as presented in Figure 5.1.

The solution of the submodel is:

$$\vec{y} = A^{-1}.\vec{a},$$

where matrix A^{-1} is the inverse of matrix A.

To find $\vec{y}$, it is sufficient to determine beforehand the ten parameters and five variables exogenous to the submodel.

Future values of the ten parameters have already been estimated in the preceding sections. They are again listed below (for 1985, 1990, and 2000, respectively) for easy reference:

c_1 (in Mtoe)	−11.33	−11.33	−11.33
c_2	1.0206	1.0206	1.0206
g (in percentage)	7.3	11.6	16.0
s (in percentage)	20	15	8
x (in percentage)	5	10	20
r_1 (in percentage)	103.8	104.1	104.5
r_2 (in percentage)	2.3	3.0	4.0
r_3 (in percentage)	0.2	0.2	0.3
b_1 (in Mtoe)	4.6	7.4	14.6
b_2 (in percentage)	2.2	2.2	2.2

Future magnitudes of the five variables exogenous to the submodel are determined as follows:

1. PCP has already been projected in Chapter 4 (see p. 41) as follows for 1985, 1990, and 2000, respectively:

PCP (in Mtoe) 1,172.5 1,295 1,431 (1)[6]

2. GDP is projected in Appendix 8 (see Table A8.4), in billion 1970 dollars at constant 1970 prices, as follows for 1985, 1990, and 2000, respectively:

GDP 123.7 176.9 319.8

3. PGL is estimated in the section below on the basis of the programmes and perspectives of Arab countries in the natural gas field as reported in Chapter 6.

4. ECP and EPP are estimated in Chapter 7 (see Table 7.2) as follows for 1985, 1990, and 2000, respectively:

ECP (in Mtoe) 2.0 3 4 (4)
EPP (in Mtoe) 22.9 32 45 (5)

NATURAL GAS LIQUIDS

A synthesis of the programmes and perspectives of Arab countries in the natural gas field as reported in Chapter 6 results in NGL projections for the Arab world as shown in Table 5.1.

Using the relevant conversion factors in Table A1.1, future magnitudes of the Arab world's production of NGL would, thus, be for 1985, 1990, and 2000, respectively:

PGL (Mtoe) 100.1 107 138 (3)

The main Arab NGL producer would continue to be Algeria, followed by Saudi Arabia. These two countries' combined share in the total, however, is expected to decline from almost 74 percent in 1985 to less than 68 percent by the turn of the century. The bulk of the remainder would be supplied by the UAE, Kuwait, the LAJ, Iraq, and Qatar, in that order—these five countries accounting altogether for 25 percent of the total in 1985 and almost 30 percent in 2000. More precisely, country contributions are projected to be as shown in Table 5.2.

Table 5.1

Projection of Arab NGL Production, 1985, 1990, and 2000 (Mt).

	1985	1990	2000
Liquefied Petroleum Gas (LPG)	45.8	50.1	70.4
Natural Gasolene (NGN)	11.1	11.8	17.0
Plant Condensate (PC)	29.1	29.4	30.7
Total	86.0	91.3	118.1

Table 5.2

Country Contributions to Arab NGL Production, 1985, 1990, and 2000 (percentage).

	1985	1990	2000
Algeria	47	46	39
Saudi Arabia	27	25	29
UAE	8	9	11
Kuwait	6	6	5
LAJ	6	6	5
Iraq	2	3	5
Qatar	3	3	3
Other Arab Countries	1	2	3
Arab Total	100	100	100

A growing percentage of Arab NGL output is anticipated to be used locally, mainly in the residential and commercial sectors and in industry (refineries, petrochemical plants, etc.), but the bulk would be exported. A country by country review of NGL projects and prospects in the Arab world reveals that NGL exports would represent 92.7 percent of total production in 1985, 88.4 percent in 1990, and 84.0 percent by the turn of the century.

OIL PROJECTIONS

Now that the ten parameters and five variables exogenous to the oil projection submodel presented above have been estimated for the years 1985, 1990, and 2000, the submodel can be solved for its 11 oil variables. The results obtained are listed below for 1985, 1990, and 2000, respectively. All figures are in Mtoe.

CPP 114.9 169 315 (2)
REF 249.7 384 694 (6)

[6] The number in parentheses refers to the corresponding step in the sequence of the projections as shown in Chapter 3 (pp. 27–28).

TPP	-111.9	-183	-334	(7)	REL	0.5	1	2	(12)
RCP	259.2	399	725	(8)	R	15.7	28	61	(13)
TCP	261.2	402	729	(9)	BNK	28.7	33	40	(14)
XCP	911.3	893	702	(10)	XPP	183.3	257	432	(15)
RNG	5.7	12	28	(11)					

SIX
NATURAL GAS

This chapter reviews programmes and perspectives of the Arab world in the natural gas field, after a brief discussion of the situation in the area. Although natural gas liquids (NGL) are excluded from the natural gas variables of the energy balance model presented in Table 3.1,[1] NGL projects are reported here because they are necessary for the estimation of net natural gas output[2]. On the basis of country programmes and perspectives, the Arab world's production, net exports, and domestic uses of natural gas are projected for 1985, 1990, and 2000.

THE SITUATION

At the beginning of 1980 Arab proved reserves of natural gas stood at about 420 Tcf. This amount was accounted for by 14 countries, all of which possessed both associated and unassociated gas reserves.

Associated gas is dissolved in the oil at the reservoir temperature and pressure and is necessarily released when crude is brought to the surface temperature and atmospheric pressure. It sometimes also consists of a gas cap above the oil in the reservoir, but this type of gas is rarely produced until after the crude has been extracted, since its earlier production would reduce the yield of oil. Certain underground hydrocarbon structures only contain natural gas, which is then called unassociated or free gas.

Dissolved gas and cap gas generally represent around 15 percent of the energy content of the oil with which they are associated. Thus, a comparison between Arab proved reserves of crude oil and of natural gas (341 Bb and 421 Tcf, respectively, at the beginning of 1980) suggests that approximately 60 percent of gas reserves in the Arab world consists of associated gas. This proportion reduces to 20 percent when a similar comparison is made for the whole world. The discrepancy between the two percentages tends to confirm the fact that there are plentiful resources of unassociated gas in the Arab world that have not yet been proved. This is also reflected in the fact that the Arab world accounts for only 16 percent of world proved natural gas reserves, whereas its share of world oil reserves exceeds 53 percent.

Natural gas exploration was not extensively carried out by the international oil companies in the Arab world when gas was cheap, in particular after the discovery of vast gas fields in the Western world, specially in the North Sea. Anyway, associated gas was rarely collected and utilized in the area, except when it was used in the operating companies' own installations or reinjected to maintain reservoir pressure. The great majority was flared or vented. Bearing in mind that the gas so released generally represents 10 to 12 percent of the energy content of the oil with which it is associated, it is estimated that the equivalent of about 10 Bb of oil has so far been lost in the Arab world, enough

[1] They are included under petroleum products (see Appendix 1, p. 103).
[2] See Appendix 1, p. 104.

to meet 70 percent of the total energy demand of the USA in 1980.[3]

Between 1960 and 1978 natural gas utilization in the Arab world (net of reinjection) increased more than 25-fold, and it is expected to witness considerable growth in the future. Natural gas is used as an energy source and as raw material for domestic purposes and for export. It serves as fuel for the generation of electricity, the desalination of water, the refining of crude oil, and the production of aluminum, cement, steel, glass, and other industrial products. It provides the oil companies with the energy required for their operations and in their installations. Its various components are used as feedstock in a number of petrochemical processes (mainly methane and ethane, but also C_3 and higher). It is utilized for the production of NGL, liquefied natural gas (LNG), and methanol.

The processing of natural gas into NGL, LNG, and methanol is mainly an export-oriented industry, but NGL are also used locally in refineries, in petrochemical plants, and in the commercial and residential sectors. As for methanol, it could be utilized as produced (in liquid form) to fuel power plants, but its most important uses to date are in automobiles (as an alternative to gasolene) and in fuel cells.

By 1980, NGL were being produced in ten Arab countries (in order in which they began production): Algeria, Kuwait, Saudi Arabia, LAJ, Egypt, Qatar, UAE, Iraq, Bahrain, and Oman. LNG was being produced by three countries (in order in which they began production): Algeria, LAJ, and UAE. During the 1980s it is anticipated that NGL would also be produced in the SAR, Sudan, and Tunisia and that Qatar would become the fourth Arab gas exporter. By the turn of the century it is projected that Saudi Arabia would be producing and exporting methanol.

There has been a worldwide controversy regarding the economics of LNG production and export. Gas buyers and sellers are price takers, since it is the price of oil that determines to a large extent the price of gas. High costs of gas gathering, desulphurization, dehydration, separation, transportation to the liquefaction plant, liquefaction, transportation by tanker and regasification in the consuming country, as well as the soaring costs of LNG plants and tankers, leave the producer with a final value representing 30 to 40 percent of the selling price to the consuming country. As for the buyer, he would have to pay more if oil prices rose, but he would be stuck with overpriced gas in case prices fell below the agreed contract floor-price, which may itself be indexed against inflation. Furthermore, approximately 25 percent of primary energy is lost in the processing and transportation of LNG, and this also contributes to increased costs. Moreover, there is the additional concern that an LNG tanker explosion in a port could cause severe damage to life and property.

Gas pipeline transport, even for long distances, seems today to be gaining ground at the expense of LNG[4]. In this connexion, it is worth mentioning a cost-benefit analysis that has been carried out comparing the returns of two hypothetical gas transport schemes from the Gulf to Europe, namely, a pipeline linking the Saudi Arabian eastern province to Munich and an LNG tanker route from the Saudi eastern coast to Marseilles via the Suez Canal. The study concluded that the pipeline option was superior to the LNG option [13].

A gas utilization alternative to LNG trade that bears more comparative advantage for the Arab world would be to substitute gas for oil wherever feasible in the domestic economy and to export the surplus gas by pipeline to neighbouring countries or even further. For long-distance trade (over 6,500 km) production and export of methanol would also be a better alternative because transportation is cheaper than for LNG, although the technology may be more complicated.

Whatever the type of natural gas utilization projects used in the Arab world, it is expected that considerable amounts of gas will have to be pro-

[3] Estimated at 78,400 trillion British Thermal Units (BTU) or the equivalent of 14.3 Bb of crude oil (*Oil and Gas Journal*, 28 January 1980).

[4] See, for example, the case of Algeria reported below.

duced to meet growing demand. Associated gas may not be produced in sufficient quantities in certain countries, since output depends on the amount of crude extracted and that amount is subjected to various national and international, economic and noneconomic factors. A viable industry based on the utilization of natural gas as fuel and as raw material should, however, have regular and durable gas supply sources. It is, therefore, imperative that unassociated gas fields be developed at a rapid pace and that gas exploration be stepped up in Arab countries, so as to ensure the security and adequacy of future supplies.

COUNTRY PROGRAMMES AND PERSPECTIVES[5]

Algeria

Algeria possesses the largest natural gas resources in the Arab world. Proved reserves are put at 132 Tcf (almost one-third of Arab reserves), and some estimates even reach 250 Tcf. Almost all the gas is unassociated. The main field is at Hassi R'Mel, 500 km south of Algiers, one of the two largest gas reservoirs in the world, with 70 Tcf of proved reserves. In 1978 gross Algerian production rose by 22 percent to 1.15 Tcf, but net production[6] increased by as much as 61 percent to 490 Bcf, because of a significant decline in the share of flared gas (from 44 percent in 1977 to less than 38 percent in 1978). Most of the gas is "wet," and the condensate derived from it (about 6.2 Mt per Bcf) is particularly useful for the petrochemical industry.

Algeria is at present, and will probably remain for some time, the world's largest exporter of LNG. Exports started in 1964, and 14 long-term agreements have so far been concluded, eight with Western European countries and six with the USA. To meet these commitments, expansions of liquefaction facilities at Arzew and Skikda are being carried out, and the construction of a new plant near Algiers is scheduled. Firm Algerian LNG capacity is expected to evolve as follows: 795 Bcf as of 1978–1979, coming from two plants at Arzew and one at Skikda; 1.72 Tcf as of 1981–1982, when two additional plants at Arzew will have come on stream; and 2.57 Tcf in the late 1980s, after a second plant at Skikda and the plant near Algiers will have become operational.

Moreover, Algeria will export natural gas in gaseous form as of the early 1980s, using a pipeline having a capacity of 512 Bcf per year and running from Hassi R'Mel to Minerbio in northern Italy via Tunisia and Sicily. The pipeline will be operating at some 80 percent of capacity initially and is expected to reach full capacity in the latter part of the 1980s. On the other hand, preliminary work has begun on a western Mediterranean pipeline, which will be routed under the sea to Almeira in Spain. It is expected to start operation in the late 1980s at half capacity. Full capacity of over 1 Tcf would have been reached by 2000.

Algeria has also planned for a significant expansion in the domestic consumption of natural gas. The distribution network is expected to extend by 1985 to 32 additional villages, thus raising the number of consumers to some 800,000, compared to 300,000 in 1976. The authorities forecast that gross final consumption of natural gas would increase from 46 Bcf in 1978 to 79 Bcf in 1980, 250 Bcf in 1985, and 537 Bcf in 1990. Between 1990 and 2000 it is projected that an average annual growth rate of 10 percent would prevail, which is less than half the 1980–1990 rate.

An impressive expansion programme is also underway with regard to NGL production, within the framework of an overall hydrocarbon development plan. Associated and unassociated wet gas will be processed at plants in Arzew and Skikda for LPG and in the Hassi R'Mel, Alrar, and Rhourde Nouss regions for both condensate and LPG. The total annual output is expected to reach more than 27 Mt of condensate and 13 Mt of LPG as of mid-1982, as compared to less than 5.3 and 0.5 Mt, respectively, in 1978. A supplementary capacity of 5 Mt of LPG is also anticipated to be added in stages, as of the late 1980s, to the LNG plants at Arzew.

[5] This review covers the 14 Arab countries that possessed proved natural gas reserves as of the beginning of 1980.
[6] Net of gas reinjected, flared, vented, or otherwise wasted.

Bahrain

Proved gas reserves are put at 9 Tcf, although some estimates reach almost twice this amount. The natural gas produced, both associated and free, is of good quality (low sulphur content) and conveniently located. Net production reached 84 Bcf in 1977 and was used in the aluminium smelter, the refinery, power generation, and water desalination. Another 37 Bcf were produced but were reinjected to pressurize the oil field. It is expected that net production will have reached 150 Bcf by 1982, implying a growth of more than 14 percent per annum, on the average, between 1972 and 1982. This impressive increase is largely due to the important expansions that have been taking place since 1973 in power generation and water desalination, and these activities are almost entirely gas-fueled in Bahrain. It is believed that natural gas utilization will not exceed 170 Bcf in 1985, and a 4 percent average annual growth is expected thereafter.

Apart from its present uses, natural gas will be utilized in Bahrain for the extraction of NGL and the production of petrochemicals. An NGL project, to be completed in January 1980, is expected to have a feed capacity of 100 Mcf/d of associated gas and an annual output of 155,000 t of LPG and 125,000 t of NGN, with 85 Mcf/d of residual dry gas. A two-stage expansion to 400 Mcf/d of the plant capacity is anticipated to be completed in the early 1990s. The products will partly supply the local market, including the contemplated four petrochemical plants, but the bulk will be exported.

Egypt

Proved reserves of natural gas are currently estimated at 3.75 Tcf, excluding the latest discovery by Elf-Aquitaine some 40 miles north of Alexandria in the Mediterranean. Four gas fields account for 88 percent of the country's reserves: Abu Qir (1.2 Tcf), Abu Gharadig (0.8 Tcf), Abu Madhi (0.8 Tcf), and Amal (0.5 Tcf). The remainder (0.45 Tcf) is associated gas in the oil fields of the Gulf of Suez (El-Morgan, July, Ramadan, and Block 382). Net production in 1978 approached 160 Mcf/d, coming from the first three gas fields mentioned above. The gas was processed for the extraction of 34,000 t of LPG and 142,000 t of NGN, and the residual dry gas was used as raw material in the petrochemical industry and as fuel in electricity generation and in the production of cement, steel, and textiles. Natural gas from the Abu Gharadig field will also be supplied in the near future to four districts in Cairo as domestic fuel to replace LPG. It is anticipated that net production from the three northern gas fields, together with NGL extraction, will double by 1986 and will witness a 3.5 percent average annual growth thereafter.

Work on a project to harness associated gas and, eventually, the reserves of the Amal gas field in the Gulf of Suez is expected to start soon with the assistance of the World Bank. The project would consist of gathering, processing, and transporting associated gas (about 100 Mcf/d released in 1979), which is presently being flared except for a nominal amount used in the oil fields. NGL would first be recovered from the gas at Ras Shukeir 235 miles south of Cairo, and the residual dry gas, up to 80 Mcf/d, would be transported to the city of Suez through a 180-mile pipeline. The stripped gas would be used as feedstock in an existing fertilizers plant (14 Mcf/d), where it would displace naphtha, and as fuel in a 300 MW power station (45 Mcf/d), a cement plant, and other industries (15 Mcf/d), where it would displace fuel oil. Pending the commissioning of the power plant in 1983, surplus gas would be piped to Cairo to supplement gas supplies from Abu Gharadig. The project is expected to be completed in 1981. Total output anticipated to be recovered by the system during the 20-year life of the project would be 570 Bcf of dry gas and 1.86 Mt of NGL.

Iraq

Proved reserves of natural gas are estimated at 27.5 Tcf. Production has so far been from associated gas. In 1978 less than 16 percent of the gas released was actually utilized, amounting to some 60 Bcf. An important gas gathering, processing, transportation, and distribution programme was initiated during the second half of the 1970s. It consisted of extracting propane and butanes (LPG) from associated gas produced along with crude oil from the northern and southern oil fields for domestic usage and for export and of utilizing the residual dry gas in local industries.

Three NGL plants have so far been completed under this programme, at Tajy near Baghdad, Kirkuk, and an industrial area south of Zubair in the Basrah Governorate. The plants yield a combined output of about 0.8 Mt of LPG annually from the processing of some 350 Mcf/d of wet gas. Under construction is a project designed to treat about 540 Mcf/d of associated gas from the northern (Kirkuk, Bai Hassan, and Jambur) oil fields in order to produce some 1.2 Mt of LPG and 423,000 t of sulphur per year. Yet another project under consideration for the 1990s consists of an NGL plant at Zubair industrial area, with an annual capacity of 3.3 Mt of LPG to be extracted from associated gas released from the southern oil fields (Rumailah).

Part of the LPG to be produced under the natural gas utilization programme would be used locally as fuel in the residential and commercial sectors and as raw material in the industrial sector (petrochemical plants, refineries, etc.). The remainder would be exported (mainly to Japan). As for the residual dry gas, which is projected to be in the region of 285 Bcf in 1985, 400 Bcf in 1990, and 750 Bcf in 2000, it would be used as electricity and refinery fuel and as raw material in the petrochemical industry. The Iraqi government, after having studied the possibility of liquefying dry gas for export, seems now to have completely dismissed the idea of having an LNG plant.

Kuwait

In Kuwait, where natural gas reserves are estimated at 33.5 Tcf, about 44 percent of the associated gas released was flared or reinjected in 1978; the remainder (about 220 Bcf) was utilized in NGL extraction, power generation and water desalination, refineries, the production of nitrogen fertilizers and petrochemicals, and commercial and residential buildings. NGL production at Mina Al-Ahmadi amounted to 1.73 Mt in 1978 (1.19 Mt of LPG and 0.54 Mt of NGN), about 95 percent of which was exported, mainly to Japan.

A major gas utilization programme has been underway since 1976, which consists of a gas gathering system, an NGL plant, and a petrochemical complex for the production of olefines and aromatics in the Shuaiba industrial area. The gas liquefaction plant, scheduled for completion in October 1979, has been designed to handle 1.68 Bcf/d of associated gas (corresponding to a crude oil production exceeding 3.5 Mb/d) moved from 25 gathering centres in the southeastern, western, and northern oil fields, so as to yield 4.89 Mt of LPG and 1.55 Mt of NGN. However, total NGL output from this project is not likely to exceed 3.6 Mt as long as the 2 Mb/d ceiling on crude production (excluding the Kuwaiti share of Neutral Zone output) remains in force. The 3.6 Mt of NGL would be exported to North America (2.1 Mt), Japan (1.1 Mt), and Europe. The remaining lean-off gases would be used in the production of olefines at Shuaiba, in gas-based industries in the country, and as fuel gas for Kuwaiti consumers.

Under this programme, however, a shortage of some 0.4–0.8 Bcf/d is forecast during the projection period in the supply of associated gas. This gap is expected to be filled either by moving unassociated gas from the Burgan field, where drilling is underway with a high probability of success, or by partial conversion to low-sulphur fuel oil of natural gas-fed facilities. The latter alternative, however, would be used as a last resort, because of the considerable costs involved in view of the high sulphur content of Kuwaiti oil.

It is assumed here that the 2 Mb/d crude output ceiling would remain in force throughout the projection period and that a maximum of 5 percent growth in unassociated natural gas production would be maintained after 1985, reflecting conservation measures taken by the authorities.

Libyan Arab Jamahiriya

The LAJ has some 24 Tcf of proved natural gas reserves, both associated and free. Before the 1970s the gas produced in association with oil had been either flared or reinjected to maintain pressure in the oil fields. As of 1971, however, associated gas has been processed for NGL extraction, with the residual dry gas either exported as LNG, reinjected, or, as of 1978, used as raw material in the petrochemical industry. Natural gas actually utilized amounted to 562 Bcf in 1978.

A number of gas processing plants are currently operated by three companies. First, the NGL/LNG complex at Marsa Brega is a state-owned venture producing some 3.6 Mt of NGL mainly for export, and nearly 100,000 b/d of LNG (around 350 Mcf/d) were sold to Italy (two-thirds) and Spain (one-third) under long-term contracts. Feed gas (about 400 Mcf/d) comes mainly from the Zelten and Raguba fields. Second, Occidental of Libya has built an NGL plant on the Intisar field, which processes some 700 Mcf/d for the extraction of less than 1 Mt of liquids pipelined to Zueitina. Third, about 130 Mcf/d treated in Oasis of Libya facilities yield one-half Mt of condensate.

The lean-off dry gases (methane and ethane) that are not liquefied and exported as LNG are either reinjected or used as raw material (in a methanol plant and in a fertilizers plant) and as fuel in certain industries. The domestic utilization of natural gas is planned to increase significantly in the future with the rapid development of gas-fed activities (a second ammonia plant, a steel plant, and other industries). The authorities expect net domestic requirements of natural gas to reach 158 Mcf/d in 1980 and 366 Mcf/d in 1985, and a 5 percent growth rate is anticipated thereafter. On the other hand, NGL production is projected to remain at the same level throughout the 1980s (about 5 Mt) before expanding gradually to reach 6.4 Mt by 2000.

Morocco

Proved reserves of natural gas are currently estimated at 25 Bcf, mostly of the unassociated type. The country has been producing gas since 1953 and utilizing it for domestic purposes. Net output amounted to 2.7 Bcf in 1978. It is projected here that net production in 1980 would be in the region of 2.6 Bcf (the 1973–1978 average) and that an annual rate of decline of 8 percent would prevail thereafter, which would allow for the country's modest reserves proved so far to last until the turn of the century.

Oman

Proved natural gas reserves have been estimated by the authorities at nearly 5 Tcf (85 percent of which is unassociated) but may reach 8.5 Tcf. This uncertainty stems from the fact that the country's unassociated gas resources have not so far been fully assessed. Up to 1977 natural gas had been flared or used for secondary oil recovery in some fields (reinjection). A gas utilization programme is underway, whereby natural gas from Yibal and Fahud fields would be processed for NGL extraction and the residual gas moved by pipeline to Ghubrah 325 km away, near Muscat on the coast. There it would be used as fuel for power generation and water desalination, and, at a later stage, as fuel in a planned cement factory and a projected refinery, and as raw material in a contemplated nitrogen fertilizers plant. The gas pipeline was completed in May 1978, with a capacity of 130 Mcf/d, which may be raised to 200 Mcf/d upon increasing pipeline pressure. Throughput, however, did not exceed 50 Mcf/d in 1978, because gas was confined to fuel the power and desalination plant at Ghubrah.

Two NGL plants have been under construction at Fahud and Yibal. The former, scheduled for completion by early 1980, will process 49 Mcf/d of associated gas to produce 2,900 b/d of NGL. The latter would yield 4,700 b/d of NGL (of which 150 b/d of LPG for domestic consumption) to be extracted from 64 Mcf/d of feed gas. In addition, some 280 b/d of NGL have been produced since 1978 at Saih Rawl field using 19 Mcf/d of associated gas and have been added to crude oil output.

A project to liquefy natural gas and to export it as LNG has been considered by the Omani government, but the inherent problems (high investment costs, marketing problems, etc.) associated with such an undertaking may have influenced the decision of the authorities to delete it from the priority list of projects to be implemented in the country in the foreseeable future.

The size of the natural gas reserves so far proved in Oman would allow for a 9 percent growth in output for about 25 years as of 1985, when net production is expected to be in the region of 130 Mcf/d.

Qatar

Qatar ranks third in the Arab world, after Algeria and Saudi Arabia, as regards the size of its proved natural gas reserves, currently estimated at 60 Tcf. Net output approached 350 Mcf/d in 1978, consisting of both associated and free gas, which was used as fuel for power generation and water desalination (200 Mcf/d), in cement and steel production, in refining and in the oil fields, and as raw material and fuel in the fertilizers plant at Umm Said.

An NGL plant was completed at Umm Said industrial area by January 1975 to treat associated gas from the onshore oil fields. The plant was destroyed by explosion and fire in April 1977. It was scheduled to be back in full operation by mid-1980. It consists of a gas collection and initial processing system at Fahahil near the Dukhan field, which releases the 340 Mcf/d needed in the plant. The liquids separated at Fahahil are moved by pipeline to the plant at Umm Said, where they yield, after fractionation, 712,000 t of LPG and 164,000 t of NGN at full capacity. A second NGL plant, to be fully operational by mid-1980, will also be located at Umm Said. It is expected to utilize 295 Mcf/d of associated gas from the offshore oil fields (Idd El Shargi, Maydan Mahzam, and Bul Hanine) to produce 730,000 t of LPG and 330,000 t of NGN at full capacity. Almost all Qatar's NGL output will be exported.

The lean-off dry gases from the two NGL plants, composed of methane and ethane, will amount to about 530 Mcf/d. Methane-rich gas (470 Mcf/d) will be routed to the state gas distribution network, while ethane-rich gas (60 Mcf/d) will feed the petrochemical industry.

The authorities expect domestic requirements of dry natural gas to reach 690 Mcf/d by 1980, and they are anticipated to have doubled by 2000, implying an average annual growth rate of about 3.5 percent. These forecasts, however, exclude processing losses resulting from the production of LNG or methanol, which is projected to start in the late 1980s.

This LNG or methanol project would be based on the output of a major unassociated gas field discovered in the northwestern part of the Shell offshore concession near Halul Island. The producing capacity of the field is estimated at about 2 Bcf/d, but the plant would be designed to handle 1.2 Bcf/d (worth 8.7 Mtoe after liquefaction, net of processing losses). The plant is assumed to run at two-thirds of capacity (0.8 Bcf/d) in the first few years of operation, before reaching full capacity during the second half of the 1990s. The LNG or methanol produced would be exported to Japan.

Regarding NGL prospects in Qatar, it is anticipated that the daily output of 5,300 t to be reached during the second half of 1980 would have doubled by the turn of the century.

Saudi Arabia

Saudi Arabia possesses the second largest natural gas resources in the Arab world, after Algeria. Proved reserves are estimated at about 98 Tcf, which is more than 23 percent of the Arab total. Natural gas utilization has been expanding in recent years, both in absolute and relative terms, mainly in reinjection, NGL extraction, power generation, water desalination, refineries, petrochemical production, and a number of other gas-consuming industrial activities. Nevertheless, the amount of flared gas has remained very important, and in 1978 about 1.2 Tcf (the heat equivalent of 240 Mb of crude oil, or 1.5 times the total domestic energy requirements of the Kingdom in that year), representing three-quarters of the total associated gas released, was lost.

The state-owned Petromin has assigned Aramco a huge gas utilization programme, launched in 1975, which will stand upon completion in the early 1980s as the cornerstone of the Kingdom's development in the years ahead and will have a considerable impact on world NGL trade. The programme, originally expected to handle 6 Bcf/d, is now designed to use 4 Bcf/d of associated gas to produce NGL, ethane, sweetened residue gas, and sulphur. Facilities with capacity for collecting, processing, and treating 1 Bcf/d and extracting and fractionating some 300,000 b/d of NGL (including Aramco's own production) have been in full operation since 1979 at Berri, Abqaiq, Ras Tanura, Abu Ali, and Jubail. Facilities to handle another 3 Bcf/d from Ghawar field, which would yield 637,000 b/d of NGL and ethane at Shedgum and Uthmaniyah plants to be separated at Ju'aymah and Yanbu fractionation centres, were scheduled to begin coming on stream in 1980. An original plan to gather and process an additional 2 Bcf/d from Safaniyah offshore oil field and Khurais onshore oil field has been deferred but may well be revived in the 1990s.

In sum, the Saudi associated gas utilization programme will be producing before 1985 about 16.5 Mt per year of LPG, 6.3 Mt per year of NGN, 0.49 Bcf/d of ethane, 1.35 Bcf/d of sweetened residue gas (methane), and 1.4 Mt per year of elemental sulphur. The NGL amounts are, furthermore, projected to be increased by 50 percent during the 1990s.

Part of the NGL produced will be consumed locally, and the remainder will be exported. Ethane and methane gases will provide fuel and feedstock for existing and future petrochemical plants at Jubail on the Gulf and at Yanbu on the Red Sea. They will also be used in power stations, water desalination plants, a steel mill, an aluminium smelter, refineries, and other industries. It is also expected that underground storage facilities of the various products will complement the Saudi master programme in order to allow flexibility in balancing future supply and demand.

Based on the authorities expectations for 1988, it is projected that domestic requirements of ethane and methane gases would reach some 23 Mtoe in 1985, 36 Mtoe in 1990, and 71 Mtoe in 2000.

Finally, a methanol plant, which had been considered back in 1973 for installation in Saudi Arabia to supply clean energy from the Gulf to both coasts of North and South America and to Japan, is projected to be constructed some time in the 1990s and to be exporting some 12 Mt of methanol by the turn of the century.

Sudan

Two modest natural gas fields have been recently discovered around the Red Sea coast near Port Sudan, with total estimated reserves of 179 Bcf (131 Bcf at Suakin field and 48 Bcf at Bashayir field). The potential for more gas finds is considered good. Moreover, the authorities have confirmed that crude oil has been recently discovered in Sudan. Thus, proved reserves of both unassociated and associated gas may well increase in the future.

The authorities believe that current reserves allow for a production of about 17 Mcf/d, from which 1,158 b/d of light condensate can be extracted. The residual dry gas would be used, for instance, as fuel in power generation, cotton oil seed processing, and cement manufacture and as raw material in the production of fertilizers.

It is projected here that the gas and condensate output levels mentioned above would prevail up to 1990, with a 10 percent average annual growth for the rest of the projection period.

Syrian Arab Republic

The SAR has so far proved 1.5 Tcf of natural gas reserves, both associated and free. Proved and probable reserves, however, are put at about 3.4 Tcf by the authorities. Net associated gas production amounted to nearly 52 Mcf/d in 1978 and was used for domestic purposes. The size of proved reserves would allow for appreciable increases in natural gas utilization in the future. It is projected that net production would rise by an average of 7 percent annually between 1978 and 1985. The growth rate is anticipated to reach 10 percent after 1985, when the country's unassociated gas resources would start contributing on a significant scale to production. Gas would be mainly used as fuel in power generation, in the Homs and Banias refineries, and as raw material in a future fertilizers plant to be located in the Homs area.

A gas processing plant is expected to be completed in 1982 in the northern part of the country, with an annual capacity of 58,000 t of LPG intended for local use. Output from this plant is projected to increase gradually to 160,000 t by the turn of the century.

Tunisia

Tunisia's associated and free gas reserves are currently estimated at 6 Tcf. Net production approached 24 Mcf/d in 1978 and is expected to average about 29 Mcf/d in 1980. The size of proved reserves should allow for an annual growth rate in gas utilization of around 15 percent after 1980, which could be sustained for more than 30 years. Natural gas has been mainly used, as of 1971, to fuel electricity plants, and this is expected to continue until the late 1980s. Thereafter, other gas uses are anticipated to develop, such as extracting NGL, fueling a number of domestic and industrial activities, and feeding future petrochemical plants.

Since production would partly consist of wet gas, it is projected that a gas processing plant would be built during the second half of the 1980s, which would produce some 60,000 t of NGL in 1990 and 375,000 t in 2000.

United Arab Emirates

Proved reserves of natural gas are put at about 21 Tcf, more than 90 percent of which is in Abu Dhabi. Almost all the gas so far proved is associated. However, a major gas field has been discovered recently 35 km east of Das Island, offshore from Abu Dhabi, the reserves of which have not been fully assessed yet and, therefore, have not been included in the amount mentioned above.

Gas utilization in the UAE goes back to 1964, when small amounts started being used on site in oil company operations in Abu Dhabi. Other gas uses developed as of 1971 and increased at a rapid pace. In 1978 total gas released in association with the Federation's crude oil production approached 1.6 Bcf/d, but more than two-thirds of this amount was flared. The rest was processed into NGL (about 360,000 t of LPG and 68,000 t of NGN), 99 percent of which was exported, and into LNG all for export (1.3 Mt), while the residue gas was used locally.

There are at present four natural gas utilization projects on stream or under construction in the UAE. The first project is an NGL/LNG plant, which started operation in 1977 at Das Island in Abu Dhabi. The plant comprises two identical trains with a capacity to process 224 Mcf/d of wet gas each. The total supply of feed-gas and fuel-gas is about 550 Mcf/d. Output at full capacity consists of 1.08 Mt of LPG, 0.18 Mt of NGN, and 2.2 Mt of LNG, most of which to be sold to Japan under a 20-year agreement. The main source of the feed-gas is associated gas from the Umm Shaif offshore oil field, but this is insufficient to operate the plant at full capacity because of the ceiling recently imposed by the authorities on oil production from that field. A short-term solution is envisaged to draw on cap gas from the same field, pending the completion of a pipeline, which will move associated gas from the Lower Zakum field to the Das Island plant. The project has been encountering technical problems ever since it started up at the beginning of 1977, but it is expected that full capacity operation would be reached in the early 1980s.

The second project, scheduled for completion in September 1980, would extract NGL from associated gas produced from Abu Dhabi's onshore fields (Asab, Bab, Bu Hasa, and Sahil). The initial processing is to be located at Bu Hasa and the fractionation plant at Ruwais near the projected export terminal at Jebel Dhanna, where a 120,000 b/d refinery would be completed by mid-1981 and a 2,000 t/d fertilizers plant is operating. On the basis of oil production at full rated capacity of 1.3 Mb/d from the four onshore fields, the output of associated gas would average 1.07 Bcf/d, from which could be extracted 114,000 b/d of LPG and 71,000 t of NGN and PC. The remaining dry gas would be used in the industrial area of Jebel Dhanna to fuel the projected refinery and feed the fertilizers plant, and in Abu Dhabi city for power generation and water desalination, with the surplus reinjected into Bab field's gas cap. Under study is also the possibility to process the gas at a later stage into LNG or methanol for export to Japan. The NGL plant will operate at about two-thirds of its capacity as long as the ceiling imposed on oil production from the onshore fields remains in force. It is anticipated that this proportion will rise to 80 percent by 1985 and to 100 percent by 1990. It is also projected that the lean-off gases would be liquefied and exported as of the late 1980s.

The third project, to be located at the Jebel Ali industrial area in Dubai, is scheduled for completion in 1980. It is designed to process some 140 Mcf/d of associated gas from the three Fateh offshore oil fields for NGL extraction and separation. Annual output would comprise 450,000 t of LPG and 200,000 t of NGN, 70 percent of which would be imported by Japan under a 15-year contract. The residue dry gas would fuel an aluminium smelter, due to start production in 1980, and a refinery of a capacity of 50,000 to 100,000 b/d, to be commissioned in the early 1980s, both of which would be located at the Jebel Ali industrial complex.

As for the fourth project, Umm Al-Qaiwain would supply Dubai, starting in 1980 or 1981, with 60 Mcf/d of natural gas coming from an offshore field discovered in 1976. A marine pipeline would carry the gas to Umm Al-Qaiwain city to supply a planned power plant and other industries, while the bulk of the gas would be moved to Dubai for use in industry, particularly the above-mentioned aluminium smelter and the refinery at Jebel Ali.

Finally, it is anticipated that the Federation's total dry gas (both associated and free) utilization would increase at an average rate of 15 percent between 1978 and 1985, 10 percent between 1985 and 1990, and 5 percent between 1990 and 2000. It is also projected that both NGL and LNG production would also grow by 5 percent per annum during the last decade of this century.

NATURAL GAS PROJECTIONS

On the basis of the information included in the preceding section, an estimation is made here of the magnitudes in 1985, 1990, and 2000 of the six natural gas variables appearing in the energy balance model presented in Table 3.1. Conversion factors, definitions, and other technical information contained in Appendix 1 are used.

Production of Natural Gas

PNG is equal to natural gas actually collected and utilized in uses other than reinjection. It is also the net of the decrease in volume resulting from processing for NGL extraction. A synthesis of the country information included in the section above results in the following Arab world projections for 1985, 1990, and 2000, respectively:

Production of natural gas (in Tcf)	5.7	9.1	14.5	
PNG (in Mtoe)	151.4	239	382	(16)[7]

The main Arab producer would continue to be Algeria, which would be responsible for more than 45 percent of total Arab natural gas output during the projection period. Algeria would be followed by Saudi Arabia, the UAE, Qatar, Kuwait, Iraq, and the LAJ, in that order; these six countries account altogether for almost one-half of the Arab total. More precisely, country contributions are projected to be as shown in Table 6.1.

Table 6.1

Country Contributions to Arab Natural Gas Production, 1985, 1990, and 2000 (percentage).

	1985	1990	2000
Algeria	46	50	43
Saudi Arabia	15	15	22
UAE	8	8	9
Qatar	5	7	7
Kuwait	9	6	4
Iraq	5	4	5
LAJ	5	4	3
Other Arab Countries	7	6	7
Arab Total	100	100	100

On the other hand, the country information included in the preceding section allows for the derivation of the future magnitudes of NGL production in the Arab world. Since such production, however, is accounted for under petroleum products in the energy balance model (and denoted PGL), its projected magnitudes have been reported in Chapter 5.

Net Exports of Natural Gas

This variable does not include future intraregional trade in natural gas (by pipeline), since the corresponding flows would cancel out in a regional perspective. Thus, XNG concerns net natural gas exports from the Arab world as a whole.

An examination of the relevant country information included in the previous section results in projections of natural gas exports from the Arab world as shown in Table 6.2.

Using the relevant conversion factors in Table A1.1, future magnitudes of the Arab world's net exports of natural gas would thus be for 1985, 1990, and 2000, respectively:

XNG (in Mtoe)	63.6	113	147	(17)

Recall that XNG does not include NGL exports, which are accounted for under variable XPP in the energy balance model (see p. 26).

[7]The number in parentheses refers to the corresponding step in the sequence of the projections as shown in Chapter 3 (pp. 27-28).

Table 6.2

Projection of Arab Natural Gas Exports, 1985, 1990, and 2000

	1985	1990	2000
LNG or Methanol Exports (in Mt)			
Algeria	35.3	52.6	52.6
LAJ	2.6	2.6	2.6
Qatar	–	4.4	6.6
Saudi Arabia	–	–	12.0
UAE	2.2	5.7	9.3
Total	40.1	65.3	83.1
Exports by Pipeline (in Tcf)			
Algeria	0.4	1.0	1.6

Total Domestic Requirements of Natural Gas

From the identity (see p. 27, identity 6):

$$TNG = PNG - XNG,$$

future magnitudes of domestic natural gas requirements in the Arab world are estimated as follows for 1985, 1990, and 2000, respectively:

TNG (in Mtoe) 87.8 126 235 (18)

Natural Gas Fueling Thermoelectricity Plants

Future magnitudes of this variable will be estimated in Chapter 7 (see Table 7.2) as follows for 1985, 1990, and 2000, respectively:

ENG (in Mtoe) 21.9 38 92 (19)

Refineries' Own Use of Natural Gas

Arab refineries' own use of natural gas has been projected in Chapter 5 (see p. 50) as follows for 1985, 1990, and 2000, respectively:

RNG (in Mtoe) 5.7 12 28 (11)

Gross Final Consumption of Natural Gas

From the identity (see p. 27, identity 7):

$$CNG = TNG - ENG - RNG,$$

future magnitudes of gross final consumption of natural gas in the Arab world are derived as follows for 1985, 1990, and 2000, respectively:

CNG (in Mtoe) 60.2 76 115 (20)

SEVEN
ELECTRICITY

Only one-half of the 160 million Arabs have access to electricity. In 1978 Arab power production averaged 440 kWh per capita, which was 20 percent higher than in the rest of the developing world but represented only 7 percent of the electricity output per head in the OECD area [14, 15, 4]. By 2000 Arab per capita generation would average 2.3 GWh, which would then be 140 percent higher than the projected level in the rest of the developing world but would represent only 20 percent of the expected electricity output per head in the OECD area.

This chapter, on the basis of a discussion of the programmes and perspectives of each of the 21 Arab countries up to 2000 in the field of conventional thermal and primary electricity, attempts to estimate the future magnitudes of the 13 electricity variables appearing in the energy balance model presented in Table 3.1.

CONVENTIONAL THERMAL ELECTRICITY

Conventional thermal (or secondary) electricity has been and will continue to be the major source of power supply in the Arab world taken as a whole. Plants fired with natural gas, heavy and middle petroleum distillates, and, to a much lesser extent, with crude oil and coal were responsible in 1978 for a gross output of 52 TWh or 78 percent of total Arab electricity production. This amount is projected to be multiplied by 10 by the turn of the century, when conventional thermal generation would contribute 81 percent to Arab power supply. Average thermal efficiency in the Arab world would also rise from less than 26 percent in 1978 to more than 32 percent in 2000, due to continuing managerial and technical improvements and to some waste heat recovery schemes.

Country programmes and perspectives in this field are summarized below.

Algeria

Algeria's conventional thermal electricity production reached 4.85 TWh in 1978, five times as much as in 1965. The main supplies come from three thermal plants at Algiers, Annaba and Oran. Other stations are under construction at Annaba, Oran, and Skikda, and further thermal units are planned for Algiers, Arzew, Hassi Messaoud, Hassi R'mel, Jijel, and M'Sila. The authorities expect that total installed capacity of thermal plants would reach 3,100 MW by 1985, generating a gross output of 15.4 TWh. This implies a sustained growth of 15 percent per annum, on the average, over the 20-year period 1965–1985. A somewhat less ambitious rate of 11.4 percent is predicted between 1985 and 1990. Total electrification of the country should have been completed by then. A 10 percent annual increase in thermal generation is projected thereafter.

The 1960s witnessed a gradual decline of the role of coal as fuel for thermal power generation in Algeria. Natural gas started early in that decade to be used as electricity fuel, and steam turbines were switching from coal to gas. By 1967 the share of natural gas in total fuel inputs had reached 40 percent (in heat equivalent), while that of coal had declined to 15 percent, the remainder being fuel oil and gas oil. By 1977 the share of gas was 90 percent, and no coal was being burnt in power plants. The authorities expect that all thermal units will be gas-fueled as of 1980. As for the thermal efficiency ratio, which had been fluctuating around 27 percent up to the mid-1970s, it approached 30 percent in 1977. It is anticipated that it will gradually improve to reach 35 percent in the latter part of the 1990s.

Bahrain

In Bahrain electricity has been produced solely by conventional thermal plants, mainly gas or steam turbines fueled with natural gas. In 1978 four stations were supplying electricity to the public, at Jafir (133 MW), Muharraq (39 MW), Sitra (120 MW), and Rifaa' (40 MW). In addition, the Bahrain Petroleum Company (BAPCO) and the aluminium smelter (ALBA) have their own installations (60 and 300 MW, respectively). Of the six power stations operating at present in the country, only the Muharraq standby plant is fueled with diesel oil, so that gas-fired turbines constitute 97 percent of the total in terms of power generation, and this proportion is likely to reach 100 percent as of 1985.

Between 1972 and 1978 electricity output in Bahrain grew by 20 percent per annum, to reach about 1.3 TWh in 1978. The Rifaa' power plant is scheduled to be operating at full capacity (200 MW) by mid-1980. In that year generation for public use is expected to approach 1.4 TWh, with an average annual increase of 12 percent up to 1985, 10 percent between 1985 and 1990, and 8 percent thereafter. As for BAPCO and ALBA output (about 270 GWh in 1978, combined) it is anticipated to grow at 5 percent annually.

The thermal efficiency ratio has been fluctuating between 22 and 25 percent since 1970, but it is expected to increase due to planned waste heat recovery schemes. The ratio is projected to have risen to 30 percent by 1985, before growing gradually to reach 35 percent in 2000.

Democratic Yemen

Power plants in Democratic Yemen, which are entirely of the conventional thermal type, produced 244 GWh in 1978 for a generating capacity of 56 MW, implying a load factor[1] of 50 percent. Although electricity output since 1968 grew by less than 3 percent per annum, the country's five-year plan forecasts an average yearly increase approaching 12 percent between 1978 and 1983. The Public Corporation for Electric Power (PCEP) predicts a 6 percent annual growth between 1983 and 1990. Generating capacity is expected to reach around 200 MW by 1987 in order to sustain future electricity demand. It is further assumed that the 6 percent growth rate in power generation will continue to prevail through the 1990s.

Middle and heavy distillates have been and will remain the sole fuel inputs for electricity generation in Democratic Yemen. As for the thermal efficiency ratio, the PCEP estimates it at about 35 percent (the 1975–1978 average) up to 1990, but it may well reach 37 percent by 2000.

Djibouti

In Djibouti electricity has been produced by the thermal plant at Boulaos, which consisted in 1978 of six units with a total capacity of 29 MW. Electricity output grew by an average of more than 13 percent per annum since 1960, to reach 93 GWh in 1978. Between 1980 and 1983 the government envisions adding four more units totalling about 26 MW to the Boulaos plant, and two further units are anticipated to be in operation by 1988. After 1990 it will be necessary to install a second thermoelectricity plant in the country in order to cope with growing demand. Total electricity generation is anticipated to reach about 195 GWh in 1985, implying a load factor of 40 percent as compared to 37 percent in 1978. Demand for electricity is projected to increase by an annual average of 10 percent between 1985 and 1990 and by about 8 percent thereafter. This would imply an installed capacity of 75 MW in 1990 with a load factor of 48 percent. Capacity would then have to be doubled during the course of the 1990s in order to meet demand in 2000, with a load factor in excess of 50 percent.

The thermal efficiency ratio in Djibouti has recently averaged 34 percent. It is assumed that it

[1] The load factor is the time of operation in percentage of total time, assuming that total installed capacity is put to use. The load factor is sometimes called plant factor.

will increase slowly so as to be in the neighborhood of 37 percent by the end of the century. As for electricity fuel inputs, middle and heavy distillates are expected to continue to feed the thermal plants.

Egypt

In Egypt conventional thermal electricity generation accounted in 1978 for 42 percent of the country's total output of 15.5 TWh. The Egyptian Electricity Authority has projected thermal power requirements to grow by 20 percent per annum between 1978 and 1985. This is because hydroelectricity generation will remain stagnant at about 9 TWh during the period, and nuclear power is not expected to be introduced before the late 1980s. The following five years are anticipated to witness a much more moderate annual increase (6.3 percent), which would further decline during the 1990s (5.2 percent). This lower growth during 1986–2000 as compared to the 1978–1985 forecasts is due to the expectation that the share of primary electricity in total generation would increase from 28 percent in 1985 to 35 percent in 1990 and 48 percent in 2000.

In 1978 about 15 percent of Egypt's 1,155 MW thermal electric system was fueled with natural gas, while the bulk of the steam stations and combustion turbines was fed with heavy fuel oil. With the rapid development of unassociated and associated natural gas utilization in the future (see p. 54), this percentage is expected to increase significantly in the coming years and approach 24 percent in 1985, before growing at a more moderate pace to reach 25 percent in 1990 and 27 percent in 2000. Some coal coming from the Sinai desert (see p. 89) is also projected to be burnt in a few stations.

The average efficiency ratio of conventional thermal power plants, which stood at 23 percent in 1973–1975 and 24 percent in 1976–1977, is estimated to continue to increase so as to be in the neighbourhood of 28 percent in 1985, 30 percent in 1990, and 35 percent in 2000.

Iraq

Iraq's electricity sector has witnessed an impressive development in the 1970s, with conventional thermal stations contributing the bulk of total generation (nearly 92 percent in 1978). The rapid growth in total electricity supply experienced since 1972 (about 18 percent per annum, on the average) is expected by the authorities to continue through 1985. In that year output from thermal plants would reach 15.7 TWh, representing about three-quarters of the total. Overall power generation would then increase by an average of 12 percent annually between 1985 and 1990 and by 8 percent (half the 1975–1990 rate) thereafter. This would imply that electricity production from conventional thermal plants would approach 27 TWh in 1990 and 57 TWh by 2000, while the remainder (27 and 29 percent of the total, respectively) would be essentially generated by hydroelectric and nuclear power plants.

The thermal efficiency ratio of conventional thermal plants has been steadily on the rise in Iraq, reaching about 29 percent in 1978–1979 as compared to 22 percent in the early 1960s. This upward trend is likely to be maintained in the future due to continuing managerial and technical improvements and to some waste heat recovery schemes, so that thermal efficiency will gradually tend to reach about 35 percent by the turn of the century.

Thermal plants in Iraq have been fueled with heavy and middle distillates, natural gas as well as crude oil, in varying proportions. While petroleum products have been the main fuel inputs in the 1960s, the share of natural gas has been consistently increasing and reached about 60 percent of the total in 1978–1979. This ascending trend is also likely to be maintained in the future. It is, therefore, anticipated that natural gas will be responsible for 75 percent (in heat value) of total conventional thermal electricity generation in 1990 and for 90 percent in 2000. The share of crude oil will, consequently, decrease gradually from 12 percent in 1978 to 4 percent at the end of the century.

Jordan

In Jordan conventional thermal plants have been the unique source of electricity supply. An installed capacity of about 300 MW, consisting of diesel generators and steam and gas turbines, produced 703 GWh in 1978. The authorities have forecast that maximum demand would reach 510 MW in 1985, 770 MW in 1990, and about 1.5 GW in 2000.

In order to meet that demand, Jordan is embarking on a nationwide development programme of the electricity sector. The main features of this programme include 1) the expansion of the Hussain thermal power station at Zarqa (20 km northwest of Amman), which upon completion in 1982 will have a total capacity of about 300 MW and will supply electric power to the northern and central areas of Jordan for domestic and industrial uses; 2) the construction of a steam-powered plant at Aqaba, which will be the country's largest power station, with an ultimate capacity of 1.2 GW to be installed in ten stages starting in 1985 and ending in the latter part of the 1990s; 3) the installation in the 1990s of a 300 MW plant at Qatrana, 80 km south of Amman.

The Jordanian authorities expect that total electricity generation would be in the neighbourhood of 2.9 TWh in 1985, 4.4 TWh in 1990, and 8.8 TWh in 2000. Of these amounts, conventional thermal electricity will represent virtually 100 percent in 1985, 96 percent in 1990, and 95 percent by the turn of the century.

The thermal efficiency ratio has been averaging 31 percent in Jordan in recent years. It is anticipated to improve gradually to reach about 37 percent by 2000. As for thermal electricity fuel inputs, they would continue to consist of heavy and middle distillates. Special mention should be made, however, of the possibility of burning domestic shale oil in the power plants in the future. In fact, preliminary drilling in the shale-rich Lajjun area (20 km west of Qatrana) has recently indicated that the quality of the oil shale there is good enough to fuel electricity stations.

Kuwait

Electricity in Kuwait has so far been supplied by conventional thermal power stations, with a generating capacity of 1.7 GW in 1978. Output in that year reached 7.5 TWh, implying a growth rate of 13 percent since 1970 compared to 24 percent during the 1960s. The authorities expect electricity demand to increase by an average of 12 percent per annum between 1978 and 1985. This will be met by adding 2.4 GW to the country's generating capacity, in the form of eight thermal generators of 300 MW each to be supplied and installed by a Japanese group and completed in early 1984. Between 1985 and 1990 thermal electricity generation is anticipated to grow by 7 percent annually, on the average, implying an addition of 1.2 GW to total installed capacity. A further addition of 1.2 GW in conventional thermal capacity will have to be achieved during the 1990s in order to cope with rising demand. By 2000 total electricity output would reach about 38 TWh, of which thermal generation would account for nearly three-quarters, the remainder to be represented by nuclear electricity (see p. 76).

Conventional thermal power plants in Kuwait have been fueled with natural gas. In view of the latter's alternative utilization scheme in progress and its limited supply, however, the authorities have decided to start burning heavy refinery products in the power stations as of 1979. Natural gas is expected to provide not more than 21 percent (in heat value) of total thermal electricity fuel by 1985, and it is anticipated that this percentage will continue to decline so as to approach zero towards the end of the century.

The thermal efficiency ratio has been continuously improving in Kuwait and averaged 39 percent in 1978. This upward trend is projected to be maintained in the future, whereby thermal efficiency would reach 43 percent by 2000.

Lebanon

In Lebanon a seven-year plan (1977–1983) prepared in early 1977 by the national electricity company, Electricité du Liban (EDL), had to be revised in 1979 after the events of July and October 1978, which caused nearly as much damage to the country's power installations as the 1975–1976 civil war. Before installing new equipment, EDL is aiming at restoring the generating capacity of 1975. This task should be completed during 1980, when thermal electricity production would have recovered its level of 1973 (1.3 TWh). Between 1980 and 1985 EDL is expecting to double its total power production equipment and network installations.

It is anticipated that the 1970–1974 growth record for total electricity supply in Lebanon will prevail during the first half of the 1980s (less than 13 percent), followed by an average annual increase of 11 percent between 1985 and 1990 (similar to the performance of the decade ended in 1974) and of 6 percent up to 2000. This would imply a conventional thermal generation of about 3.4, 6.2, and 11.8 TWh in 1985, 1990, and 2000, respectively, which would necessitate an addition by 1990 of some 600 MW to EDL's 1985 thermal capacity and a further addition of 1.5 to 1.8 GW by the turn of the century.

The overall thermal efficiency ratio in Lebanon has been fluctuating between 23 and 27 percent. The latter value is assumed for 1985, followed by a gradual improvement that will reach seven percentage points 15 years later. As for thermal electricity fuel inputs, they will continue to be middle and heavy petroleum products.

Libyan Arab Jamahiriya

The LAJ has so far relied on conventional thermal power plants for electricity generation. Demand has been increasing at a rapid pace, and output in 1978 was five times as much as in 1970. The Secretariat of State for Electricity (SSE) has recently prepared a draft long-term plan for the electricity sector. According to this plan, the total capacity of conventional thermal electricity plants would be in the neighbourhood of 4.2 GW in 1985, 7.0 GW in 1990, and 11.1 GW in 2000. The corresponding power supply would amount to about 9.2, 12.7, and 25.0 TWh, respectively. This implies an average annual growth rate in thermal generation of about 15 percent between 1978 and 1985 and 7 percent between 1985 and 2000, as compared to 22 percent during the decade ended in 1978.

The thermal efficiency ratio in the LAJ has been recently averaging 22 percent, but the SSE predicts an improvement to 27 percent in 1985, 29 percent in 1990, and almost 32 percent by the turn of the century. As for thermal electricity fuel inputs, the plan provides for a gradual switch from light to heavy distillates, the latter representing 92 percent of the total as of 1990. Natural gas is not anticipated to be burnt in the stations; instead, its increasing supply would be allocated to more profitable uses.

Mauritania

Electricity generation, transmission and distribution in Mauritania has been since 1975 the responsibility of SONELEC (Société nationale d'eau et d'électricité), which in 1978 produced 46 GWh with an installed thermal capacity of 53 MW. The capital Nouakchott and the industrial city Nouadhibou are responsible for the bulk of electricity output (90 percent in 1979). Moreover, the national mining company SNIM (Société nationale industrielle et minière) has its own electricity installations, with a thermal capacity of 32 MW that generated about 59 GWh in 1978.

SONELEC has planned for an additional thermal capacity of 64 MW in Nouakchott, 32 MW in Nouadhibou, and 1 MW in Dakhla. Further, the company expects thermal output to increase by 17 percent annually, on the average, between 1978 and 1982. It is projected that this growth rate will be maintained through 1985, while electricity production at SNIM would increase by 5 percent per annum between 1978 and 1985. The country's conventional thermal power output is anticipated to rise by 10 percent per annum during the second half of the 1980s and by 8 percent for the rest of the century.

Average thermal efficiency in Mauritania has been gradually improving and reached 30 percent in 1978. It is assumed that this upward trend will continue, so that the ratio would stand at about 35 percent by 2000. As for the fuel to be burnt in the stations, it will still consist of middle and heavy petroleum distillates.

Morocco

The bulk of Morocco's thermal power installations consists of steam turbines fueled with coal and fuel oil. Thermal generation has grown significantly in the past 20 years, from less than 100 GWh in the late 1950s and early 1960s to some 2.6 TWh in 1978. To cope with the future increase in the demand for electricity, which is expected to maintain the 9 percent per annum trend witnessed since 1966 up to 1985 with some slowdown thereafter (8 percent between 1985 and 1990 and 7 percent after 1990), the authorities have embarked on an important power development programme comprising both primary (hydro, nuclear, solar) and secondary (conventional thermal) electricity schemes. The former will be examined in the following sections. The latter will include the commissioning of the steam-powered plant at Mohammedia in four phases of 150 MW each, the Jorf Lasfar station, and others.

Average thermal efficiency in Morocco has been slowly improving to about 24 percent during 1975–1978, with some fluctuations. This trend is anticipated to continue, so that thermal efficiency would reach 30 percent by the turn of the century. As for the fuel burnt in the stations, the share of coal has been consistently declining from almost 100 percent in the early 1960s to about 54 percent (in heat value) in 1978. The role of coal as electricity fuel will have to decline further in relative terms simply because of the country's coal production capacity. On the basis of a 3 percent average annual increase in coal output as of 1979, solid fuels are projected to account for 45, 36, and 22 percent of total electricity fuel inputs in 1985, 1990, and 2000, respectively. The remainder will be represented by middle and heavy petroleum distillates.

Oman

In Oman the public power sector mainly consists of three unconnected systems: the northern system, the southern system, and the rural system. The capital area is supplied with electricity through the northern system, which comprises two thermal plants at Riyam Bay and at Ghubrah, with an output of 377 GWh in 1978. The southern system provides the power requirements of the city of Salalah and its surrounding area in the Dhofar region, with an estimated production of about 90 GWh in 1978. The rural system generated in 1978 some 23 GWh distributed among five regional areas covering 26 villages and small towns. Moreover, independent generators are installed in various parts of the country, mainly at hospitals, agricultural farms, armed forces headquarters, and the Island of Masira. Finally, there are a number of autoproducers, the largest one being Petroleum Development (Oman) Limited, the oil company operating in the country.

Electricity output in Oman totalled about 660 GWh in 1978, entirely thermally generated. The 1970s witnessed an impressive growth in the power sector, whereby supply increased by an average annual rate of about 30 percent, as compared to 17 percent in the 1960s. The authorities have planned for an electricity production in excess of 1.2 TWh in 1980, more than half of which (650 GWh) will be provided by the Ghubrah power and desalination plant, which will be the sole supplier of the capital area as of September 1980, after the disconnexion of Riyam station. Output in the capital area is planned to increase by 20 percent per annum during the 1980s, while generation in the rest of the country is expected to double during the same period. After 1990, Oman's total thermal production is projected to grow by 8 percent annually, on the average, so as to reach about 11.5 TWh in 2000.

Average thermal efficiency in Oman is projected to maintain its recent level of 35 percent throughout.[2] As for thermal fuel inputs, the share of natural gas, which has been rapidly increasing since 1967 and reached 80 percent (in heat value) in 1978, is expected to remain at that level through 1985, before rising gradually to attain 85 percent in 2000. The share of crude oil in the total amount of fuel to be burnt in the thermal stations is projected to gradually decline from 13 percent recently to 2 percent by the turn of the century. The remainder would be accounted for by refinery products.

Qatar

Qatar's electricity output reached 1.5 TWh in 1978, generated by an installed conventional thermal capacity of 577 MW, more than 95 percent of which was accounted for by the Ras Abu Aboud power station, the Ras Abu Fontas power and desalination plant, and the electricity station at Umm Said fertilizers plant. The 1970s witnessed an average annual growth of about 25 percent in power production, as compared to 21 percent during the 1960s. The Ministry of Electricity and Water expects that the former rate will prevail through 1980, before dropping to a little more than 10 percent between 1980 and 1985 and to 7

[2] On the basis of information obtained from the Ministry of Communications in Oman, thermal efficiency at Ghubrah would range between 18 and 19 percent during the 1980s. This low ratio is due to the fact that the fuel consumption data communicated to the ECWA secretariat are those for power generation as well as water desalination.

percent thereafter. Accordingly, thermal generation would stand at about 10.7 TWh by the turn of the century.

Thermal efficiency is anticipated to continue to improve gradually from 29 percent in the late 1970s to 35 percent in 2000. Natural gas would continue to be the predominant electricity fuel input, whereby its share in the total would rise from about 80 percent (in heat value) in 1978 to 95 percent in 2000. The other types of fuel burnt in the stations, namely, crude oil and diesel oil, will witness a gradual decline in their relative contribution, from 17 and 3 percent in 1978 to 5 percent and almost nil, respectively, by the turn of the century.

Saudi Arabia

Saudi Arabia has given a very high priority to the rapid development of electricity supply. Although installed capacity reached in 1978 (3,935 MW) more than ten times its level of 1972 (380 MW), officials believe that there is still a large element of suppressed demand. The need for considerable additional generating capacity and for expanding and integrating the transmission and distribution network in order to meet sharply increasing demand is likely to be one of the most pressing domestic problems facing the government in the future. The Ministry of Industry and Electricity, through its executive arm the Public Electricity Corporation, is primarily responsible for the development of the electricity sector on a national scale. There are, however, important institutions that do not at present come directly under the Ministry, notably the Saudi Consolidated Electric Company in the Eastern Province, managed by Aramco, and the Riyadh Electricity Company. In addition, a great number of industrial establishments have their own generating facilities. Finally, there are numerous small private electricity companies operating under franchise in local areas.

Tremendous efforts have been made in Saudi Arabia towards the integration of the national electricity system, which in the past consisted of hundreds of small private companies subsidized by the government. Considerable progress has been achieved, but there is still a long way to go. The ultimate goal may not be a national grid, since the distances involved would make its installation enormously expensive. Instead, there is serious thinking about three or four regional grids, which would cover the north, the west and southwest Red Sea coasts, and the central and eastern regions.

The Kingdom's electricity output, entirely generated from conventional thermal power plants, increased by an average of 25 percent per annum in the 1970s, as compared to 15 percent in the 1960s. Taking the 1975–1978 period separately, the growth rate almost reached 29 percent. The authorities expect total electricity demand to be in the region of 48 TWh in 1988, implying an average annual increase in excess of 18 percent in ten years. A 10 percent growth rate is projected for the rest of the century. Almost all of these sharp increases in demand would be met by conventional thermal generation, while primary electricity (nuclear, solar, and heliohydro) would be responsible for a very small proportion of total output (around 1 TWh in 1990 and 2 TWh in 2000).

The efficiency ratio of conventional thermal power plants in Saudi Arabia has been slowly improving from low levels and reached 20 percent in 1977–1978. The authorities predict a continuation of this trend, so that the ratio would approach 24 percent in 1988. Accordingly, levels of about 23, 25, and 29 percent are anticipated for 1985, 1990, and 2000, respectively. As for the types of fuel burnt in the thermal stations, natural gas will continue to be the leading input, and its share in the total is projected to increase gradually from 50 percent (in heat value) to 90 percent by the turn of the century. The other fuel types used, namely, crude oil and diesel oil, will see their contribution decline from 15 and 35 percent, respectively, to 5 percent each in 2000.

Somalia

Somalia has at present a generating capacity of about 90 MW, 40 percent of which services the capital Mogadiscio. All plants are of the conventional thermal type, mainly fired with diesel oil. The authorities predict that it would be necessary to have an installed capacity of 630 MW by 2010 in order to meet rising demand. Accordingly, it is anticipated that capacity will increase by an average of 10 percent per annum up to 1990 and by 6 percent between 1990 and the turn of the century.

The load factor would average about 38, 40, and 43 percent in 1985, 1990, and 2000, respectively. Primary electricity is not expected to contribute more than 5 percent of total power output; the bulk would continue to be generated by conventional thermal plants.

Thermal efficiency is projected to improve from 20 percent at present to 30 percent in 2000, bearing in mind the country's determination to save energy. Diesel oil would continue to be the leading fuel input, but there are plans to exploit the coal and oil shale resources in the northern part of the country and to use them to fire a few thermal power stations.

Sudan

Total power generation in Sudan had by 1978 increased almost tenfold from 1960. However, electricity in the early 1960s had been exclusively thermally generated, whereas hydropower in 1978 contributed 54 percent to total output. Bearing in mind a planned annual growth of 7.5 percent in gross domestic product, it is expected that the country's demand for electricity will increase by double that rate between 1978 and 1985, i.e., 15 percent, as compared to more than 17 percent in the 1971-1978 period. The growth rate is projected to average 10 percent per annum thereafter, which implies that conventional thermal power plants would be responsible for around one-third of total generation in the future, the rest to be accounted for by primary (hydro and, to a much lesser extent, solar) electricity. Accordingly, thermal power production would increase by an annual average of about 10 percent between 1978 and 2000, which is practically a continuation of the 1971-1978 trend.

In view of Sudan's determination to apply energy conservation measures in all sectors, thermal efficiency is anticipated to improve gradually from 23 percent recently to about 30 percent by the turn of the century. As for thermal fuel inputs, which consisted exclusively of middle and heavy petroleum distillates since 1966 (small quantities of imported coal had also been used before that), their composition by type is not expected to change in the 1980s. In the 1990s, however, freshly produced natural gas would contribute some 10 percent (in heat value) to the total fuel burnt in the stations.

Syrian Arab Republic

In the SAR conventional thermal generation peaked at 969 GWh in 1972, when it represented 94 percent of total electricity supply. It has been declining since then and stood in 1978 at 438 GWh or 17 percent of total output, the rest being produced by hydropower installations. In view of the latter's limited development possibilities, the authorities have embarked on a large expansion programme of the thermal electricity sector for the 1980s, mainly concentrating on the installation of fuel oil-fired steam turbines. Thermal capacity is planned to reach about 1.6 GW in 1985 and 3.4 GW in 1990, as compared to 470 MW in 1978. The average load factor of thermal plants is expected to rise from 11 percent in 1978 to nearly 40 percent, as a result of considerable progress in integrating the network and in interconnecting the transmission system. Thermal generation would, thus, stand at about 5.6 TWh in 1985 and 11.7 TWh in 1990. It would represent in the latter year about 57 percent of total electricity production, as against 72 percent in 1985; this decline in relative terms is the consequence of the introduction of nuclear power in the late 1980s. As for the 1990s, total electricity demand is projected to increase at an average annual rate of about 8 percent, thus reaching some 45 TWh by the turn of the century. This implies a conventional thermal output approaching 30 TWh, to be generated by a capacity in the region of 9 GW.

The thermal efficiency ratio, which averaged 22 percent recently, is anticipated to improve gradually so as to reach 27 percent in 2000. As for the types of fuel to be burnt in the stations (which so far have consisted of fuel oil and diesel oil), natural gas is expected to be introduced shortly as electricity fuel, its share in the total rising from 10 percent (in heat equivalent) in 1985 to about 30 percent in 2000. Some stations would also be fired directly with crude oil, with a rising contribution that would, however, not exceed 5 percent of the total in the late 1990s.

Tunisia

Tunisia has been mainly relying on conventional thermal electricity to meet rising demand for power. About 98 to 99 percent of total generation has recently been supplied by thermal plants. Electricity demand is expected by the authorities to increase at an average annual rate of 13 percent between 1978 and 1985 (compared to 14 percent during 1975-1978), 10 percent between 1985 and 1990, and 6 percent during the 1990s. To meet this growth in demand, conventional thermal electricity would continue to be the main source of power through the 1980s, but its share in the total would decline from 98 percent in 1985 to 81 percent in 1990 and 70 percent in 2000, due to the introduction of nuclear power in the country as of 1990. Thermal generation would, therefore, stand in the neighbourhood of 4.6, 6.2, and 9.4 TWh in the three bench-mark years, respectively.

Thermal efficiency has been improving from an average of 21 percent in the early 1960s to 26 percent in recent years. This trend is anticipated to continue, so that a ratio of about 34 percent would prevail by the end of the century. After the introduction in 1971-1972 of gas-fired steam and gas turbines in Tunisia, natural gas began to be increasingly used to fuel thermal power plants. Its contribution to total fuel inputs stood at 36 percent (in heat equivalent) in 1978, the rest being represented by heavy and middle petroleum distillates. With the expected development of natural gas production in the future, its share is projected to rise gradually to reach 75 percent in 2000, thus easing up to some extent the demand for petroleum products in the country.

United Arab Emirates

In the UAE the 1970s witnessed an unprecedented development of the electricity sector. with an average growth rate of about 43 percent per annum in power supply during 1970-1978. A slowdown was expected by the authorities in 1979 and 1980, but estimated output in the latter year was still 33 percent higher than in 1978.

Each of the seven Emirates has so far been largely responsible for securing its own power supplies. There are independent electricity companies in Abu Dhabi, Dubai, Sharjah, and Ras Al-Khaimah, and the Federal Ministry of Electricity and Water is only responsible for the power supply of Ajman, Umm Al-Qaiwain, Fujaira, and the rural areas of Sharjah and Ras Al-Khaimah. This partly explains why it should take in 1980 an installed capacity of about 2.5 GW to generate a UAE total of some 5 TWh, which implies an average load factor of only 23 percent. To remedy this situation, studies are underway concerning the integration of the Federation's network and the possible installation of a gas-fueled central power plant for the country as a whole.

All power plants in the UAE are of the conventional thermal type, and primary electricity (notably solar) might contribute only negligible amounts to total supply in the future. Demand is projected to rise by an average of 12 percent annually between 1980 and 1985, 10 percent between 1985 and 1990, and 7 percent throughout the 1990s.

Thermal efficiency, which averaged 23 percent in recent years, is likely to improve gradually and reach about 28 percent towards the end of the century. Natural gas, which accounted for about three-quarters of the heat equivalent of the total of fuels burnt in the power stations in the late 1970s, is projected to increase its share to 90 percent in 2000. In contrast, petroleum products would account for 9 percent as compared to 23 percent recently, the rest being represented by crude oil.

Yemen

Yemen's public electricity supply increased by an average of 27 percent annually during the 1970s to some 160 GWh in 1979. This growth rate, although much higher than that of the 1960s (11 percent), does not reflect the real increase in demand but, rather, the rate at which supply could be expanded. Actually, suppressed demand is quite important, and there is a considerable number of unconnected potential customers. The three main cities—Sanaa, Hodeida, and Taiz—accounted in 1979 for 97 percent of the electricity produced by the Yemen General Electricity Corporation (YGEC). Other towns currently supplied by YGEC include Ibb, Dhamar, Baida, Radaa, and, in 1981-1985, Bajil, Amran, and Mufraq. In addition, the major industries have installed their own generating facilities, and many private generators are scattered around the country in the smaller towns and villages.

The stations in the three main cities are being expanded to lay the basis for a triangular national grid system. Plans include extensive rural electrification, a considerable increase in small-scale generating capacity, and the development of the transmission and distribution network. YGEC has predicted that its supplies will reach more than 900 GWh in 1985. In that year, therefore, total output could approach 1 TWh. Electricity generation is projected to increase by about 20 percent per annum during the second half of the 1980s and by 10 percent during the 1990s.

Further power supplies in Yemen will continue to be generated by conventional thermal plants, except for negligible amounts that might be provided by primary (solar, wind, biomass, geothermal) sources as of the late 1980s. Thermal efficiency, which averaged about 30 percent in recent years, is anticipated to improve gradually to about 35 percent by 2000. As for the types of fuel burnt in the thermal plants, diesel oil has so far been exclusively used. With the future installation of steam turbines in the country, heavier petroleum products are also expected to be utilized. Finally, the possible exploitation of Yemen's coal deposits (see p. 89) might result in coal contributing about 5 percent of the heat equivalent of the total amount of fuels burnt in the stations.

HYDROELECTRICITY

At present eight of the 21 Arab countries utilize hydroenergy for power generation, and in four of them (Egypt, Lebanon, Sudan, and SAR) this source is the major supplier of electricity. Hydrogeneration in the Arab world approached 15 TWh in 1978, as compared to less than 2 TWh in 1960. In relative terms, its contribution to total power supply peaked at 34 percent in 1969, before gradually declining to 22 percent in 1978. This downward trend is likely to continue in the future, and this section projects hydropower output in 2000 to account only for 6 percent of the Arab world's total electricity supply, although it would exceed by 180 percent its level of 1978 in absolute terms. By the turn of the century 14 Arab countries would be using hydroenergy to generate power in one way or another, with Egypt, Iraq, and Sudan (in that order) producing more than 80 percent of the Arab total.

Country programmes and perspectives in this field are summarized below.

Algeria

In Algeria the share of hydroelectricity in total power generation reached a peak of about 35 percent in 1968, before declining more or less regularly so as to reach 5 percent in 1978. Hydrogeneration has also been reduced in absolute terms since 1973, because of the country's increasing needs for priority uses of water, such as for irrigation and to meet municipal and industrial demand. Total installed capacity of about 287 MW mainly comes from plants at Massouring (100 MW), Algioum (90 MW), and other small stations in the Kabylia. It has been at around this level since the late 1960s and is not expected to undergo much change in the future. The authorities believe that the production level of 1977–1978 (250 GWh) could be maintained for another 25 years.

Djibouti

Djibouti has no hydropower installations at present, but prospects do exist in two areas. First, a depression could be created in the Goubed Bay (155 sq. km) at the end of the Gulf of Tajurah by building dams across the narrow passage between the Bay and the Gulf. Solar evaporation would then reduce the water level by 5 to 6 m annually, so that generating capacity would reach 5 to 6 MW after the fifth year and 12 to 13 MW in the seventeenth year. Second, the Assal Lake has a surface area of about 300 sq. km, which is 174 m below sea level. The project would involve building a 10 km water canal from the Gulf of Tajurah to the depression; this would generate power during a first stage when the depression is filling and a second stage by solar evaporation.

Egypt

In Egypt hydropower has been the most important source of electricity generation. In 1970–1977 it was responsible for more than two-thirds of total power production. As of 1978, however, hydroelectricity's share has started a downward trend with no foreseen reversal. In fact, it is expected to decline to reach 28 percent in 1985, 22 percent in 1990, and only 15 percent in 2000. This is because the river Nile accounts for virtually all the conventional hydropower potential of the country, and about 80 percent of this potential has already been harnessed at the Aswan dam (345

MW installed capacity) and the Aswan High dam (2,100 MW).

The operational capabilities of both the Aswan dams are severely constrained by conflicting irrigation needs and transmission system reliability. As such, the dependable generating capacity of both these plants is currently being assessed at less than two-thirds its nominal level, capable of generating about 9 TWh annually.

The untapped power potential of the river Nile consists of a 60 m drop from Aswan to Cairo, from which at least 350 MW are anticipated to be realized before 1990 with the extension of the Aswan High dam and the installation of generating facilities in three existing barrages at Nag Hamadi, Esna, and Assiut.

The Qattara depression in the western desert is the main other hydropower possibility. The project involves canalizing water from the Mediterranean to the depression using a 60 m descent to generate power. The depression has a surface area at zero level of 19,500 sq. km, with the deepest point at 134 m below sea level. Estimated capacity is about 640 MW for the first 12 years while the depression is filling and about 340 MW by solar evaporation thereafter. The Egyptian Electricity Authority, however, has indicated that capacity should reach a peak of 8,000 MW upon the completion of the four stages of the project. Due to the massive excavation work required, the first stage of the Qattara project is not anticipated to be completed before the late 1990s.

It is expected that the average load factor of Egypt's hydropower stations will remain through the rest of the century equal to the current effective load factor of the Aswan dams, i.e., 66 percent.

Iraq

Hydropower production started in Iraq in September 1972 when a 84 MW plant at Samarra was commissioned. With about 550 GWh, this station contributed in 1978 a little more than 8 percent to the country's total electricity output. The authorities have planned for at least seven other hydroelectric projects to be completed by the turn of the century. Installations at Dokan and Hemrin are expected to be completed in the early 1980s, with a combined capacity of 450 MW, yielding an output of 1.58 TWh. The Derbendkhan and Haditha stations should add another 740 MW to the country's hydropower capacity by 1990, with a corresponding additon of 2.48 TWh in production. Dams to be built during the course of 1990s at Mosul, Bakhma and El-Fataha are anticipated to bring total hydroelectric capacity in Iraq to more than 3 GW. This would generate a total output of 12.52 TWh in 2000, implying an overall load factor around 47 percent.

Jordan

There is no hydroelectric production in Jordan at present, despite the existence of three dams (Khaled Ibn El-Walid dam, Al-Maqarin dam, and King Talal dam). These have so far been used solely for irrigation purposes, due to the country's primary need for water. The dams have technically a combined generating capacity of 91 MW, capable of producing some 400 GWh with a 50 percent load. The authorities, however, seem determined to develop hydropower in Jordan, in view of its attractiveness as a clean, renewable source of energy that would also contribute to alleviate the fuel import bill to some extent. In this connexion, the possibility of canalizing water from the Gulf of Aqaba to the Dead Sea for power generation is under consideration. The surface area of the Dead Sea approaches 1,000 sq. km at 400 m below sea level, and the electricity that would be generated while the depression is filling, and later through solar evaporation, is considerable. The project, however, would require massive excavation work to build the 180 km water canal, thus involving heavy investment funds.

In the light of the above, it is assumed here that hydrogeneration capacity in Jordan will be in the neighbourhood of 40 MW in 1990 and 70 MW by the turn of the century.

Lebanon

In Lebanon hydropower has been produced since the early 1930s (Al-Safa station) and has gradually developed into a major source of electrical energy for the country. Generating capacity reached 246 MW in 1968 and has remained at that level since then. The national electricity company EDL operates at nearly 90 percent of capacity (of which the Litani River installations represent 70 percent), while the rest (27 MW) is owned by private stations selling their prodution to the public network.

The 1975-1976 civil war and the events of 1978 caused considerable damage to Lebanon's electric production, transmission, and distribution installations. As a result, hydropower generation had to be increased to compensate for the reduction in production of the most affected thermal stations, with the consequence of raising the overall load factor of hydroelectric plants from an average of 35 percent during 1970-1974 to 49 percent in 1978.

EDL plans do not provide for any significant expansion in the Lebanese hydropower capacity. However, the addition of 36 MW to the Litani installations at Al-Awali station, which had been planned before the civil war, may well take place by 1985. In that year the load factor is anticipated to average around 40 percent, before increasing to 45 percent in 1990 and 50 percent in 2000.

Morocco

In Morocco the contribution of hydropower to total electricity generation, which averaged as much as 90 percent during 1960-1965, has been declining since then but still represented more than 35 percent in 1978 (1,416 GWh). As of mid-1979 there were 18 hydroelectric stations having an average production potential of 1,584 GWh, two-thirds of which coming from four large plants (Afourer Ait-Ouarda, Bine El-Ouidane, Im'Fout, and Idriss the First).

The authorities are determined to fully develop the country's untapped potential. During the first half of the 1980s some 540 GWh will be added to hydropower output through the extension of the Lalla Takerkoust station and the commissioning of four new plants (Oued El-Makhazine, Al-Massira, Merija, and Dechra El-Oued). As for the rest of the century, a number of hydroelectric schemes are envisaged, which include the utilization of some 13 new water falls and the use of the Tah depression in the south (a small replica of Egypt's Qattara depression) and two smaller depressions located nearby (Hamirah and Tisfurin) to generate power. It is anticipated, in the light of these planned projects, that hydropower production will reach 2.4 TWh by 1990 and 3 TWh by 2000.

Saudi Arabia

Saudi Arabia is studying the feasibility of transforming the Gulf of Dawhat Salwa into a depression for heliohydroelectric generation. The total area involved is 6,460 sq. km, and the depression would be created by building a dam between Saudi Arabia and Bahrain and another dam between Bahrain and Qatar, of a total length of 58 km in shallow waters. The project is estimated to produce 70 MW of electrical energy at an optimum head of 12.4 m, which would be shared with Bahrain and Qatar.

Somalia

Somalia has limited possibilities for hydropower generation on the Juba River, where a plant is expected to be commissioned in the near future.

Sudan

Hydropower generation started in Sudan back in 1962, when it accounted for 2 percent of the country's electricity output. This percentage has been steadily increasing since then and reached about 54 percent during 1976-1978. Production approached 500 GWh in 1978, generated by three plants located at dams on the upper reaches of the Blue Nile and its tributary the river Atbara, with a combined capacity of 116 MW. The largest of these plants, at Roseires dam, is being expanded by another 80 MW to reach a total capacity of 170 MW.

The various cataracts and rapids on the Nile have considerable hydropower potential, which has been estimated by the authorities at about 2,770 MW from eight possible stations. Of this potential capacity, only 160 MW are presently being developed, and there are plans for an additional capacity of 800 MW to be installed by 2000.

The present load factor stands in the region of 49 percent, but future projects are planned to produce power at about 70 percent load since they would be mainly intended for electricity generation, while existing schemes have other functions such as irrigation and flood control. Accordingly, the average load factor of hydropower installations is projected to increase gradually to reach 65 percent by the turn of the century.

Syrian Arab Republic

The SAR's most important hydropower and irrigation source is the Euphrates River, which accounts for 88 percent of the country's water resources. A large basin development scheme on the Euphrates has already been completed, comprised of a reservoir, a dam, and a power station consisting of eight units of 100 MW each. Generation from this plant exceeded 2 TWh in 1978 (more than 80 percent of the country's total electricity supply) and was expected to reach a peak of 2.4 TWh in 1979, before starting to decline by about 40 GWh annually due to increased diversion of water and pumping requirements for irrigation purposes. In addition to this 800 MW Thawra plant, there are a few small hydroelectric stations with a combined capacity of 23 MW, namely, Souk Wadi Barada near Damascus (7 MW), Rastan between Hama and Homs (8 MW), and Shezar near Hama (8 MW). These small plants add some 50 GWh to the country's annual hydropower output.

There are some possibilities for further hydropower development in the SAR, notably two dams on the Euphrates and another dam on the Khabour River, a tributary to the Euphrates, with an estimated combined capacity of 300 to 400 MW. The authorities have planned for the commissioning of these stations between the late 1980s and the early 1990s. It is projected here that 300 MW will have been installed by 1990, with an additional 100 MW during the 1990s. As for the average load factor of hydropower generating installations in the country, it is estimated to gradually decline from 34 percent in 1979 to 27 percent in 1990 and stabilize at about that level for the balance of the century.

Tunisia

In Tunisia hydropower contributes a small part to total electricity generation. Four plants at El-Aroussia, Nabeur, Fernana, and Kasseb, with a combined capacity approaching 29 MW, have been producing between 20 and 70 GWh annually, the output fluctuating with the scarcity of water. Apart from a new plant of about 25 MW at Sidi Salem, which is scheduled to be commissioned in the early 1980s, prospects for further development of the country's hydropower capacity are not considered too bright. It is, therefore, projected that hydrogeneration will average some 80 GWh annually throughout the 1985-2000 period.

NUCLEAR POWER

Whether the introduction of nuclear energy in the Arab world for large-scale electricity generation is a sound option on economic, social, political and environmental grounds is an important subject that deserves careful investigations beyond the scope of the present study. It will only be stated here that the major arguments put forward by nuclear proponents—that it is a cheap and clean form of energy best able to fill the energy gap—call for serious scrutiny, particularly in a developing area endowed with tremendous hydrocarbon resources and sunlight.

Reactor Technology and Research

Plans have been reported in ten of the 21 Arab countries, eight on a commercial level and two on a research and experimentation level.

Algeria

Algeria's National Declaration (Decree No. 76 of July 1976) has explicitly opted for the establishment of an effective nuclear strategy based on self-reliance in nuclear technological development as a means to ensure a long-term energy source and at the same time give an impetus to national development in science and technology. The Centre des sciences et de la technologie nucléaires (CSTN), established in the late 1960s, initiated an ambitious programme for the development of nuclear technology and research. About one-half of Algeria's expenditures on science and technology (45 million Algerian dinars) is assigned to CSTN activities, which cover uranium processing, enrichment, reactor technology, nuclear materials, electronic simulation, theoretical and applied nuclear physics, health physics, and the nuclear fuel cycle. The authorities expect that Algeria will soon be able to manufacture and operate its own reactors.

According to available forecasts from international sources, three units of 150 MW each would be in operation by 1990, and it is anticipated that this capacity would double by 2000.

Egypt

In Egypt it will be necessary to install a number of nuclear power stations with a total generating capacity of 6,000 MW by 2000 in order to meet electricity demand, according to the Electricity Authority. In the meantime, the commissioning of two stations with a combined capacity of 2,000 MW is optimistically scheduled between 1987 and 1990. The necessary arrangements are currently being made for the installation of the first plant at Sidi Krir on the western coast near Alexandria, with a capacity of 1,000 MW. Other sites under study are in the Lake Bourollos area on the coast between Alexandria and Port Said and on the Red Sea coast.

It is projected here that nuclear power generation will be responsible for about 13 percent of total Egyptian electricity output in 1990 and for about 32 percent in 2000. These shares are lower than the 20 and 40 percent, respectively, predicted by the Electricity Authority.

Iraq

Iraq's Atomic Energy Commission was established back in 1956. Research is going on at the Nuclear Research Institute (Tuwaitha) and at the Nuclear Research Centre (Baghdad) with experimental reactors. Cooperation agreements have been concluded with France, Italy, and the USSR. A 2 MW Russian research reactor has been operating since 1968 at Tuwaitha Institute. France is reported to provide shortly a 70 MW training reactor and to install a 600 MW nuclear plant, which would be commissioned by 1985. A French fast breeder reactor is also under negotiation for later.

By 1990, six units of 150-200 MW capacity each would be in operation in the country, according to available forecasts from international sources. It is anticipated that by 2000 Iraqi nuclear capacity would reach 2,000 MW.

Kuwait

Kuwait's plans up to 2000 envision the installation early in the second half of the 1980s of a station of about 600 MW, which would be followed in the early 1990s by a plant of the same size. The acquisition of two more stations of 1,200 MW each would subsequently be considered, thus allowing for a total installed capacity of 3,600 MW by the turn of the century. A cooperation agreement has been signed with the United Kingdom. The acquisition of a 50 MW training reactor has been under consideration, as well as the establishment of a nuclear energy commission.

More recently, however, the Kuwaiti authorities have been reconsidering the country's nuclear energy programme, in view of the ever-increasing costs of reactor installation and operation. As a result, it seems likely that the implementation of the programme will be deferred for a few years at least. It is projected here that nuclear electricity will not be produced in Kuwait before the early 1990s, and that nuclear capacity will build up to some 1,800 MW by 2000.

Lebanon

In Lebanon Electricité du Liban seems to have plans for nuclear power in the future, but no indication is available concerning the possible size of the projected plant nor the date of operation.

Libyan Arab Jamahiriya

An Atomic Energy Commission was founded in the LAJ in 1975. Research is expected to start soon at Al-Fateh University in cooperation with the USSR, which may provide a 10 MW training reactor. Reports have mentioned that a 440 MW plant is to be constructed by the Russians and another 600 MW station by the French. Plans for a heavy-water reactor might also be considered. Other cooperation agreements have been concluded with Argentina and India.

In its draft long-term plan for the electricity sector prepared recently, however, the Libyan Secretariat of State for Electricity (SSE) expects that a 400 MW nuclear plant will be in operation in the country by 1990. The SEE does not foresee any increase in capacity during the 1990s.

Morocco

Morocco is negotiating with France the possibility of installing a 200 MW reactor, which could be commissioned in the mid-1980s. R & D activities have been initiated at Rabat University. According to available forecasts from international sources, two units of 200 MW each will be in operation in the country by 1990. As for 2000, installed nuclear capacity could reach 600 MW.

Saudi Arabia

Saudi Arabia has no intention at present to introduce nuclear energy on a commercial scale, but considerable emphasis is being put on R & D activities, which have started in three universities. A training reactor of 6 MW was to be installed at Dhahran University under a cooperation agreement recently concluded with France. A nuclear medicine centre has been established in Riyadh. A large multipurpose national nuclear research centre is planned by the Ministry of Petroleum and Minerals, which is at present in control of nuclear energy affairs pending the establishment in the near future of an atomic energy commission.

According to available forecasts from international sources, however, one 150 MW unit would be operating in the Kingdom by 1990. This capacity is anticipated to double by 2000.

Syrian Arab Republic

The SAR established an Atomic Energy Commission in 1976, and the authorities recently declared their intention to introduce nuclear energy on a commercial scale in the 1980s. There are plans for the installation of two units of 600 MW each, which would be in operation in 1989-1990. Two similar units are projected to be added before the turn of the century.

Tunisia

In Tunisia R & D in nuclear energy is underway at the Institut de recherche scientifique et technique. There are plans to introduce nuclear electricity in the country in the late 1980s, with the installation of a 250 MW reactor. This capacity is anticipated to triple by 2000.

An average load factor of about 60 percent is considered a likely estimate for the Arab world as a whole up to 2000.

Nuclear Fuel Availability

The effective exploration and extraction of uranium deposits in a number of Arab countries is by now an accepted national objective, which is seen to be justified by the need for a long-term regular supply of nuclear fuel as a prerequisite to establishing any independent national nuclear capacity, let alone certain alarming forecasts of a world shortage of uranium in the not too distant future. It should be noted, however, that uranium, after extraction, needs to be enriched before entering the nuclear reactor, and enrichment technology is at present the monopoly of a few countries, primarily the USA and the USSR.

Primary Deposits[3]

In **Algeria** geological mapping and ground surveys started in 1970, and exploration drilling is underway in the southern part of the country. Primary uranium ore deposition is estimated at between 28,000 and 78,000 t. In **Democratic Yemen** certain uranium-bearing and thorium-bearing concentrations of heavy sands have been reported, but recent investigations tend to indicate that they are uneconomic or marginal. Radiometric surveys have also revealed a number of interesting anomalies of uranium and thorium in granite massives. In **Egypt** geological mapping has been undertaken in various parts of the country, and extensive areas have been covered by airborne surveys for radioactivity since the late 1950s with more than 7,000 anomalies identified. Recently, significant finds have been reported in the eastern part of the Egyptian desert, near Mount Jilala El-Bahria. A uranium production plant is under construction, with an expected output of 100 t in 1981. On the other hand, some monazite (a mineral containing uranium and thorium) exists with black sands sedimented in the northern shores of the Nile Delta. Exploration is underway in **Iraq** with promising prospects. In **Jordan** carborne and hand scintillometre surveys have shown that the Zarqa-Ma'an rift valley is the

[3] As opposed to uranium associated with phosphate depositions.

strongest radioactive area in the country. Some exploration is going on in the **LAJ** in cooperation with Argentinian, French, and Japanese firms. In **Mauritania** intensive exploration programmes have been underway since 1957, including geological mapping and radiometric airborne and ground surveys—performed by France, Japan and the Total company. By 1974 numerous rich anomalies had been found. In **Morocco** widespread uranium mineralization was reported in the 1940s and 1950s by unsystematic surveys undertaken by France and the USA. A national plan of action was set up in 1968, and significant progress was made in exploration, whereby two highly radioactive areas were located. Present estimates of uranium reserves range from 47,000 to 1.54 million short tons of U_3O_8. In **Saudi Arabia** intensive exploration for radioactive mineral deposits has been carried out since the early 1960s, using airborne scintillometre and spectrometre surveys followed by some ground checking. No discrete uranium minerals were found, but certain areas were considered to warrant further investigation. Recently, however some reports indicated that uranium and thorium occurrences may well have been detected in these areas by a French firm. In **Somalia** airborne and ground surveys as well as exploration drilling have been carried out since the 1960s. In the Bur area 400 anomalies were located, of which 49 were of interest. In the Mudug province 14 anomalies were found that showed that uranium mineralization was represented exclusively by carnotite. Primary uranium ore deposition is estimated at between 6,000 and 10,000 t of U_3O_8, mainly at Wabo, Dusa-Markeb, and Mirig in the Mudug province and at Alio-Ghelle in the Bur area. In **Sudan** geological mapping followed by radiometric airborne and ground surveys revealed four areas of radioactive occurrence. Uranite has been reported in association with copper and iron ores, and thorium-bearing black sands were identified. Further surveys are being carried out in the Hofrat-En-Nahas areas in the western part of the country. In the **SAR** a team of Russian geologists undertook a geological mapping programme in the early 1960s, followed by airborne surveys that indicated some distinct radioactive zones. Exploration is at present carried out by British firms in the southern desert through field and aero-radiometric surveys. In the **UAE** radioactive anomalies located by spectrometre airborne and ground surveys have been recently confirmed to be due to potassium-rich rocks and not to uranium or thorium deposits as was originally believed. Large areas of **Yemen** abound in the same kind of rock from which uranium is being extracted elsewhere. Exploration projects, however, will require time and heavy expenditures.

Uranium From Phosphate

Uranium recovery from phosphate is a new process, which is at present the monopoly of the USA, where such plants exist in Florida and Louisiana. One of the main advantages of this process is the much shorter lead times than for primary uranium mining. Uranium can be recovered from phosphate after the latter's conversion into phosphoric acid by the wet process. Such an undertaking is commercially feasible when 1) the phosphate has a P_2O_5 content above 27 percent, a prerequisite for the commercial preparation of phosphoric acid, 2) the mineralization of phosphate rocks with uranium is not less than 0.01 percent, and 3) uranium is recovered as a by-product in the manufacture of phosphate chemical fertilizers.

The Arab world accounts for about 50 Bt of estimated phosphate reserves (at more than 27 percent P_2O_5), representing 40 percent of the world total. Uranium association with Arab phosphate ranges from 0.007 to 0.018 percent, the average being 0.01 percent. Thus, 6 Mt of U_3O_8 would be a rough estimate of how much uranium might theoretically be extracted as a by-product in fertilizer manufacture in the Arab world.

Phosphate chemical fertilizer plants designed to produce wet-process phosphoric acid are operational or under construction in **Egypt**, **Iraq**, **Jordan**, **Morocco**, the **SAR**, and **Tunisia**. Special mention should be made of **Morocco**, which accounts for three-quarters of Arab phosphate reserves and two-thirds of production and is the world's largest exporter of phosphates. A plant for the recovery of uranium from phosphate is expected to be constructed in Morocco as a joint venture with Westinghouse (USA), which would reach an export capacity of 2,000 t of yellow cake uranium by 2000. As for **Saudi Arabia**, a comprehensive feasibility study for the exploitation and processing of phosphate rock deposits in the Kingdom is near completion.

SOLAR ENERGY

This section presents a brief review of current and planned activities in solar energy R & D and applications in the Arab world. A detailed study on the subject was scheduled for completion by the end of 1980 in a cooperative effort between ECWA and OAPEC, in the context of the preparations at the Arab level for the United Nations Conference on New and Renewable Sources of Energy (Nairobi, August 1981).[4]

The sun is a source of energy of unlimited quantity. It is free, clean, safe, and widely and generously distributed in the Arab world. Saudi Arabia alone receives the equivalent of one hundred trillion (10^{14}) kWh of solar energy every day, theoretically enough to supply the electricity needs of the whole OECD area for 20 years. Moreover, solar power technology is much simpler than nuclear technology and could be easily transferred to, and assimilated by, developing countries. Investments require a much smaller foreign exchange component than nuclear energy. Solar costs are likely to follow a downward trend due to rapid technological advancements, whereas nuclear costs are constantly on the rise. Finally, solar energy may be safely used in a number of applications other than electricity generation, such as space and water heating and cooling, water desalination, water pumping, crop drying, cold storage, greenhouses, sewage treatment, industrial process heat, etc.

Interest in solar energy in Arab countries started in the universities in the late 1950s and early 1960s (Sudan, Tunisia), but it was not until R & D efforts were seriously stepped up in the Western world during the past few years that official attention was devoted to the question in the Arab world. Solar energy conferences and/or exhibitions were held in Saudi Arabia (1975, 1978), the LAJ (1976), Tunisia (1977), Bahrain (1977, 1978), Egypt (1978), and Morocco (1978). Government bodies or commissions for solar energy were established in six Arab countries, and nine solar research laboratories are already operating or planned. Annual R & D budgets add up to about $27 million in the Arab world (of which Saudi Arabia alone accounts for $15 million), compared to a federal US budget approaching $1 billion. Solar energy R & D in the Arab world is carried out in insolation (11 countries), photovoltaic conversion (seven countries), solar thermal conversion (five countries), solar storage (four countries), and concentration (two countries). Chemical conversion studies are practically nonexistent.

Solar energy ongoing and planned applications in each of the 21 Arab countries are summarized below.

Algeria

In Algeria a comprehensive feasibility study on the application of solar energy and its role in the overall energy picture by 2000 has recently been undertaken. A "solar village" is to be set up that will use solar energy in water heating and pumping, space heating and cooling, refrigeration, and thermal and photovoltaic conversion. A solar furnace built by the French in the 1950s is expected to produce steam for a thermal electricity turbine of about 30 kW. A solar thermal conversion unit of 10 kW is also planned. There is an Algerian section of COMPLES (Coopération méditerranéenne pour l'énergie solaire), which serves as a link with the international solar energy community. Cooperation is mainly with France and Germany (Federal Republic).

Bahrain

The solar energy programme in Bahrain was initiated in 1977 by the Bahrain National Oil Company (BANOCO) in cooperation with the Kuwait Institute for Scientific Research (KISR). A feasibility study was commissioned in April 1978 to study the potential of solar energy in the country, including the identification of applications and a commercialization strategy. Cooperation is also underway with Germany (Federal Republic) and the United Kingdom.

Democratic Yemen

No known solar energy activity is being considered in Democratic Yemen at present. Climatic

[4] The study in question has since then been completed and published by ECWA in *New and Renewable Energy in the Arab World,* Beirut, 1981.

conditions, however, appear quite favourable, and average solar intensity is theoretically equivalent to a power generation of around 200 kWh per sq.m per year, assuming 10 percent radiation efficiency.

Djibouti

In Djibouti a solar pump is being installed with French bilateral aid for irrigation purposes. Possible areas for future solar energy applications include the Assal Lake and the Goubed Bay, which could both become precious sources of hydroelectric generation by use of solar evaporation (see p. 72).

Egypt

In Egypt studies have indicated that direct daily solar intensity averages about 3,500 kcal per sq.m in winter and double that amount in summer, theoretically equivalent to a power generation of about 150 and 300 kWh per sq.m per year, respectively, assuming 10 percent radiation efficiency.

Solar energy use started at the turn of the century when the British built a 37 kW solar water pump. Another start took place in the early 1960s when solar water heaters were domestically produced and sold for 100 Egyptian pounds before being discontinued for lack of interest. Solar energy activity is now diversified and undertaken in cooperation with many countries, mainly Canada, France, Germany (Federal Republic), Italy, Saudi Arabia, Sweden, and the USA. Although the Egyptian solar programme is at present one of the most active and diversified in the Arab world, it seems to rely too much on outside funding for support.

The Egyptian Solar Energy Laboratory (SEL) of the National Research Centre is at present handling five projects: two thermal power plants totalling 7 kW, solar cooling, solar drying, and solar desalination. The SEL has also plans for the domestic manufacture and marketing of solar flat-plate collectors. The Solar Energy Commission, established in 1976 under the auspices of the Ministry of Electricity and Energy, is dealing with numerous projects, including the Qattara depression hydroelectric generation plant (see p. 73), solar reverse osmosis, water heating and space heating/cooling for a 100-room hotel on the north coast, a 5 kW solar pump with a cooling and freezing unit, three pilot solar water heaters of different types equipped with flat-plate collectors, 1,000 solar water heaters for domestic and community usage, various meteorological and testing stations, a complete "solar village," cooling and freezing stores for fish at the High Dam Lake, solar desalination, two (one 10 kW and one 100 kW) solar thermal conversion units, two mobile 5 kW units for desert research, and many other projects. Six universities are carrying out applied research in various aspects of solar energy use, including rural applications, which seem to hold promising prospects after the success of some demonstrations to villagers.

The private sector has also been active in promoting solar energy applications in Egypt. A 620-room hotel to be built near the Pyramids will make use of the sun for electricity generation, water and space heating, cooling, and ice making. A project for a solar water heater factory, with a production capacity of 100,000 heaters during the first year and 300,000 heaters thereafter, has been submitted to the National Industrialization and Investment Committee for approval.

Iraq

Iraq seems determined to encourage solar energy utilization, although no solar applications are yet in view in the public sector. Al-Mustansiriyah University is cooperating with the Foundation for Scientific Research to develop a solar energy programme for the country. Immediate plans are to design solar collectors with local materials for space and water heating, water desalination in remote areas, yellow corn drying in winter, greenhouse night heating in winter, solar energy use in desert zones, and the establishment of a solar energy research centre.

Jordan

Average insolation in Jordan is theoretically equivalent to a power generation of about 200 kWh per sq.m annually, with 10 percent radiation efficiency. The country's solar energy programme started in 1971 at the Royal Scientific Society (RSS), and the Department of Solar Energy was established at the RSS in 1975. Cooperation partners include Australia, France, Germany (Federal

Republic), India, and Kuwait (KISR), as well as ALECSO and the CEC. The main activities have been water desalination (such as the Aqaba desalination plant commissioned in October 1977), "plastic agriculture," greenhouses, crop drying, ground sterilization, photovoltaic telephones in rural areas and along highways (100 units installed as of August 1978), a 200 kW solar powered thermal electricity station for use in an integrated "solar village," and solar water heaters. A project for the development of a domestic solar water heater industry was started in 1972 by the RSS. There are at present two companies in Amman producing 30 heaters per day, and there are about 20 other such firms in the West Bank. Jordanian universities are not contributing much to the country's solar energy development.

Another major possibility for solar energy applications in Jordan is to link the Gulf of Aqaba with the Dead Sea by a water canal to generate power by use of solar evaporation (see p. 73).

Kuwait

Kuwait experiences a daily insolation of about 45,000 kcal per sq.m, which is theoretically equivalent to a power generation of around 2,000 kWh per sq.m per year, assuming 10 percent radiation efficiency. A major solar energy programme was initiated in September 1976 under the responsibility of the Kuwait Institute for Scientific Research (KISR). Solar heating and cooling of buildings is an area of great potential in Kuwait and the Gulf region, which is developing rapidly into a viable domestic industry, in cooperation with US institutions. A 100 kW solar thermal conversion unit will be commissioned in February 1981, in cooperation with a German (Federal Republic) firm. It is expected to generate an average of 800 kWh per day. It would be used as part of an integrated food (greenhouse)/water (desalination)/power (electricity generation) complex particularly suitable for isolated communities. Cooperative programmes have also been concluded with Bahrain and Jordan (see above).

Lebanon

Lebanon was emerging as an active seat for solar energy activities when the war started in 1975. Institutions concerned with solar energy are the National Council for Scientific Research (CNRS), the American University of Beirut, and Saint Joseph University. Close cooperation has been established between these three institutions, and emphasis is being put on solar heating and cooling of buildings, water desalination, photovoltaic conversion, insolation, and integrated solar architecture. A pilot project on solar heating of an apartment in Beirut was under implementation in 1980. The CNRS, whose representative has recently been elected Vice-President of COMPLES (Coopération méditerranéenne pour l'énergie solaire), aims at establishing a solar energy centre in Lebanon. Recently, the private sector has been showing vivid interest in the introduction of small-scale solar energy applications, particularly solar heating and cooling of buildings. Finally, a Lebanese Solar Energy Society was created in April 1980.

Libyan Arab Jamahiriya

In the LAJ solar energy activities are getting underway. There are indications that an autonomous solar research institute may be set up. A Centre for Solar Energy Studies was established at the Arab Development Institute (Tripoli) in June 1978. Solar work is also being undertaken at the Atomic Energy Commission and at two universities (Al-Fateh and Qar Yunis). Emphasis is being put on solar thermal conversion, heating and cooling of buildings, water desalination, solar drying, water pumping, and refrigeration. The first solar energy device, a water pump for irrigation purposes, was installed in the Sidi Rhuma area in May 1978. Cooperation is underway with Canadian and US firms.

Mauritania

Solar energy activities in Mauritania are at present limited to the installation of French-made water pumps for municipal and irrigation purposes. After a first rather unsuccessful attempt in 1973, a 5 kW photocell pump has been recently installed, and there are plans for six other pumps. A "solar village" at N'Takat, to be executed with French assistance, has been under consideration. Three different ministries are concerned with solar energy applications, and emphasis will be put in the future on water desalination, fish drying, cold storage, water heating, and solar electricity for rural settlements. Apart from France, cooperation is underway with Senegal.

Morocco

In Morocco solar water heaters have been known since the early 1940s. Demand has been increasing rapidly but has so far been met by imports, due to the lack of a domestic solar water heater industry. A study on the possibilities of solar energy utilization in the country has been recently prepared by the Ministry of Energy and Mines, which is at present studying a heliohydroelectric power plant project at the Tah depression (and may be at two other smaller depressions) using solar evaporation, similar to that of the Qattara depression in Egypt (see p. 74). Other plans of the Ministry include solar thermal electricity in remote areas, a solar energy research centre, and solar demonstration stations. Interest in solar energy has also been shown in three universities/schools, where projects include the establishment of a photovoltaic laboratory and solar energy applications in the mining industry. It was recently decided to establish a Moroccan section of COMPLES.

Oman

In Oman a few experimental solar water heaters were installed at Salalah by the British in 1971. In 1977 the USA also assisted in preparing a study on possible solar energy applications in the country, that recommended the use of photovoltaic cells for electricity generation and water desalination and the utilization of solar water heating in remote villages. Two villages in Dhofar were chosen for such applications. The installation of a 15 kW solar electricity plant has also been under consideration.

Qatar

In Qatar a British experimental photovoltaic generator started operating in 1977. No firm solar plans have been formulated yet, but areas of interest include solar thermal conversion, solar heating and cooling of buildings, and an integrated food/water/power complex.

Saudi Arabia

Saudi Arabia has the largest solar energy programme in the Arab world. From the first photovoltaic beacon installed by the French at Madinah Airport in the early 1960s, solar applications have been growing on ever larger scales. Serious efforts were initiated in 1969 (Dhahran), and by now four universities (Dhahran, Riyadh, Jeddah, and Dammam) are active in almost all fields of solar energy, as are a number of ministries and institutions. The Saudi Arabian Centre of Science and Technology (SANCST), established in 1977, tries to coordinate these efforts. In early 1978 the decision was taken to set up a Solar Energy Society in the Kingdom. Cooperation agreements have been concluded with Austria, France, Germany (Federal Republic), and the USA. The Saudi-US programme is the largest, extending over five years at a total cost of $100 million to be contributed equally by each party.

Amongst the most significant solar applications underway or planned in Saudi Arabia are:

1) a "solar village" to be completed by 1981 50 km outside Riyadh,
2) a solar-powered heating complex for the Airborne School at Tabuk, which is the largest project of its type in the world,
3) a huge heliostatelectricity generation project in the Eastern Province,
4) an industrial plant in Jeddah to manufacture solar components for the heating and cooling of buildings,
5) a "solar building" in Jeddah, and
6) an integrated solar energy complex at Jubail on the Gulf.

Special mention should be made of a heliohydroelectric generation project, which is still under study, whereby a depression would be created in the Gulf of Dawhat Salwa by building dams between Saudi Arabia and Bahrain and between Bahrain and Qatar. The project would be similar to that of the Qattara depression in Egypt and would have a capacity of 70 MW to produce electricity using solar evaporation (see p. 74).

Saudi Arabia has also been active in providing financial assistance to universities in Australia, Niger, and the USA in solar energy R & D.

Somalia

In Somalia direct solar radiation has been estimated to be theoretically equivalent to an annual power generation of around 200 kWh per sq.m, assuming 10 percent radiation efficiency. Solar energy activities have been carried out in cooperation with UNICEF as of 1976 and with ECA, India, Italy, UNESCO, and UNIDO as of 1978. A modest pilot solar desalination plant to supply drinking water for a fishing community at Khuda on the Indian Ocean was scheduled for completion in 1979. Another solar distillation plant of a larger size is also underway. Plans include integrated solar/wind/biogas energy utilization in rural areas.

Sudan

In Sudan solar energy has been since the early 1970s a field of interest at the Energy Research Institute and at Khartoum University. Work has been underway in insolation, heating, refrigeration, water desalination, food drying, photovoltaic conversion, and low/high temperature thermal conversion, including power plants in remote areas for electricity and irrigation purposes. Cooperation comes from Denmark, France, and the Netherlands. Two solar pumps have been installed, one at the Institute's premises in Soba for demonstration and the other at the Hillat Hamed village for the supply of domestic water. A project for a "solar village" at Umm Safari (North Kordofan) is under study.

Syrian Arab Republic

Solar energy activity in the SAR started in the mid-1970s at the Aleppo and Damascus universities, with emphasis on heating and cooling systems, solar storage and concentration, and solar cells. After the Ministry of Electricity had established a Solar Energy Committee in 1977, solar applications started moving ahead, mainly in the direction of locally manufactured solar water heaters. A housing project at Dummar is to be supplied with 500 such heaters, and a number of summer youth camps will have solar-heated water. A solar water and space heating system may also be installed at the Al-Tall Institute of Political Studies.

Tunisia

Tunisia's Institut de recherche scientifique et technique has been active in space cooling, water heating and water desalination since 1963. Three solar desalination stills were built, providing 8,200 litres of fresh water per day, but were unfortunately abandonned six years later. A National Energy Commission was established in 1977, which has been considering legislation for the promotion of solar energy applications and usage, including subsidies and tax deductions for solar users and investors, the establishment of a solar energy commission, and a photovoltaic laboratory. Interest in solar energy is also evident in universities and other institutions throughout Tunisia, with emphasis on insolation, photovoltaics, solar cooling and heating, solar electricity generation, solar water pumping, and solar cookers. Cooperation is underway with Australia, the CEC, France, Germany (Federal Republic), Italy, Sweden, Switzerland, UNEP, and the USA. A Tunisian has recently been elected President of COMPLES.

Solar energy applications already existing or underway in Tunisia include 11 photovoltaic water pumps, a small solar desalination still, a number of water heaters installed in private homes and public schools, a solar-heated swimming pool on Djerba Island, and an assembly plant for flat-plate collectors. Plans include the installation of a solar thermal power plant in the 50 to 100 kW range, the local manufacture of collectors, and their use for water and space heating.

United Arab Emirates

In the UAE the integrated food/water/power complex installed on Saadiyat Island (Abu Dhabi) in the 1960s with US assistance is one of the major solar energy applications in the Arab world. A 90 kW diesel turbine generates electricity, while the waste heat is recycled to desalinate water for drinking and growing vegetables in greenhouses. A French-made solar water pump of 1 kW is also operating at Al-Ayn in an experimental farm. Contacts with foreign groups in France, Germany (Federal Republic), Italy, Sweden, and Switzerland have been made for such solar applications as water pumping, cooling and heating of buildings, solar thermal conversion, and photovoltaic conversion. A feasibility study for the development of solar energy technology in the UAE is under preparation.

Yemen

In Yemen direct solar intensity measured in Sanaa, Hodeida, and Taiz averages about 5,000 kcal per sq.m per day, which is theoretically equivalent to a power generation of more than 200 kWh per sq.m per year, assuming 10 percent radiation efficiency. The country has been seeking US assistance in developing a solar energy programme at Sanaa University, but no solar applications have been introduced so far.

After this brief review of ongoing and planned solar energy activities in the Arab world, the virtues of this safe, nonpolluting, widespread, and renewable source of energy cannot, in conclusion, be overemphasized. Of special importance is the concept of integrated food/water/power complex (see above), which is particularly suited for isolated communities far removed from the electrical grid that only have access to sea or brackish water, and there are many such areas in the Arab world. Technology is accessible and adaptable, costs are reasonable, operation and maintenance are simple, and such a complex can meet the electrical energy, fresh water, vegetable, and poultry requirements of a community.

BIOMASS CONVERSION, GEOTHERMAL, AND WIND ENERGY

This section gives a sketchy and incomplete presentation of the potential for biomass, geothermal, and wind energy in the Arab world. Detailed studies on the availability, utilization, and prospects of these three energy sources in Arab countries were scheduled for completion at ECWA by the end of 1980, in the context of the preparations at the Arab level for the United Nations Conference on New and Renewable Sources of Energy (Nairobi, August 1981).[5]

Biomass Conversion

Energy from biomass is produced and widely utilized in the Arab world, in the sense that fuelwood, charcoal, agricultural wastes, and animal dung are used principally for domestic heating and cooking. Such traditional energy sources still represent a major part of total energy requirements in some countries. However, the interesting form of biomass energy, namely, conversion by hydropyrolysis or fermentation (biogas), is practically nonexistent. The raw materials for biomass conversion are widely available; what is essentially needed is government action to harness this important energy source.

Certain Arab countries are contemplating more seriously than others the exploitation of biomass for energy production. For instance, **Egypt** is undertaking studies in cooperation with Sweden on the possibilities of converting agricultural and animal remains into biogas for energy purposes and fertilizer production in rural areas. **Lebanon** is investigating the possible use of municipal wastes for biogas production. Studies on the possible use of biomass energy in rural areas are being carried out in **Saudi Arabia**. In **Somalia** plans for integrated solar/wind/biogas energy systems for rural areas are being formulated. **Sudan** produces annually about 13 Mt of agricultural wastes, mainly cotton stalks and bagasse, which are partly used for energy purposes by direct combustion. The authorities are now contemplating the conversion of such wastes by pyrolysis into fuel for use in boilers of sugar factories, and the relevant studies are being undertaken by the Energy Research Institute under the sponsorship of the Sudanese National Research Council. In the **SAR** there are plans for utilizing municipal wastes (about 300,000 t in Damascus alone) and agricultural wastes to produce energy and fertilizers. In **Yemen** a number of public baths (hammams) in Sanaa are reported to use municipal wastes for heat production, and there are plans for a more expanded and rational use of energy from biomass in the future.

Geothermal Energy

The Arab world lies within various geodynamic zones that allow for different types of geothermal fields. Five distinct favourable environments have been identified:

1. The Orogenic Mediterranean zone, including Morocco and the northern parts of Algeria, Tunisia, and the LAJ.
2. The Red Sea–Gulf of Aden–East Africa triple tectonical rift system, including the

[5] The studies in question have since then been completed and published by ECWA in *New and Renewable Energy in the Arab World*, Beirut, 1981.

eastern parts of Egypt and Sudan, Djibouti and Somalia, to the west; and the western part of Saudi Arabia, Yemen, and Democratic Yemen, to the east.

3. The Jordan valley fault system, including Lebanon, the southern part of the SAR, Jordan, and Iraq.
4. A number of intracratonic volcanic centres, such as in the southern part of Algeria, the LAJ, the southwestern part of Sudan, and the central part of Saudi Arabia.
5. Large sedimentary basins, including north-central Africa and the Arabian Peninsula.

Within the first four environments, medium (80 to 150°C) to high (150 to 350°C) temperature geothermal sources could be expected at relatively shallow depths, thus allowing for the operation of small-scale electricity generators (1 kW to 1 MW) and, in some cases, larger plants (10 to 100 MW). As for the fifth environment, hot water reservoirs could be found in medium depths, which might be used for electricity generation through binary fluid systems or for direct heat production.

Geothermal sources have been identified in a number of regions in the Arab world, and investigations are underway to assess their potential contribution to the energy balance of the countries concerned. For instance, in **Democratic Yemen** a surface spring yielding water at 80°C in the vicinity of Abyan near Aden will provide energy to a cement plant under construction there. Another 80°C water spring at Hamiah near Mukalla is planned for use in coastal area power generation with assistance from the World Bank. There is also a hot spring at Sidara that gives birth to Wadi Hajar, the only perrenial river in the country. In **Djibouti** exploration has been going on since 1969 in Daguiron-Gelafi, Goubed, and the Abbe Lake. In 1974–1975 drilling in the Asab field revealed considerable amounts of hot, wet steam that could yield a power generating capacity of 1.5 to 2 MW. The country's geothermal energy potential is considerable, but development financing seems to be a major constraint. In **Egypt** a number of wells and natural springs yielding water at 40 to 60°C have been found around the Gulf of Suez, down the western coast on the Red Sea, in the Halwan area, and in various parts of the western desert. Such low temperature waters are expected to be harnessed in the future for domestic and commercial uses. Moreover, the prospects of discovering geothermal sources at temperatures up to 150°C, which could be utilized for electricity generation through binary systems, is considered good. Finally, the possibility exists that high temperature sources (above 150°C) lie within the earth's crust under the Red Sea; these would be directly used for electricity production. In **Jordan** there are good prospects for the exploitation of geothermal energy, particularly in the Jordan River Valley, which is the site of a number of hot springs, and also in the Zarqa-Ma'an rift valley. Upon the recommendation of a team of French and Italian experts who visited the country in 1975, the Jordanian authorities have been investigating the question with the assistance of the United Nations. In **Lebanon** at Sammakieh 6 km east of the Lebanese-Syrian border check point at Arida, there is an artesian well 547 m deep with water flowing to the surface at a temperature above 40°C. In **Saudi Arabia** there are plans for the exploitation of the Kingdom's geothermal energy potential. In **Somalia** exploration is underway, and the authorities are placing high hopes on the contribution of geothermal sources to the country's future energy balance. In the **SAR** geothermal sources have been discovered in the Orontes Valley and the Palmyra Mountains. The Supreme Council for Sciences believes that there are good prospects for more finds in the future. Studies to harness this energy source are underway. In **Tunisia** the possibilities of exploiting domestic geothermal resources are being investigated. In **Yemen** geothermal potentials do exist, particularly in the area of recent volcanic activity 25 km east of Dhamar (a town about 100 km southeast of Sanaa) with temperatures reaching 180°C of dry heat on the surface. There are also hot springs in various parts of the country, such as in the Damth area (about 150 km southeast of Sanaa), where a number of localities carry a toponymic denomination starting with "hammam." Some assistance in studying the possibilities of exploiting these sources in Yemen came from Italy in 1975 and 1976.

Geothermal energy is not so well known in most Arab countries, and interest in that energy source has so far been less vivid than in other new and renewable sources such as solar energy. This situation is probably due to the fact that the technology and economics of geothermal energy are variable according to geological situations, not to mention the importance of the initial investments in some cases.

Wind Energy

The wind, like the sun, is a free, clean source of energy, widely distributed in the Arab world. It is well-adapted to the needs of rural communities. Its technology is simple, and it can generally be harnessed wherever wind is available at certain levels of velocity. Interest in wind energy has recently been growing in the Arab world, where a number of countries are carrying out studies and experiments to assess the potential of this renewable energy source.

For instance, in **Democratic Yemen** there are wind-recording stations in Aden and Mukalla, but the best potential exists in the slopes and valleys of the hinterland. In **Egypt** two areas, around Marsa Matrouh on the Mediterranean and around Horghada on the Red Sea, have so far recorded average wind speed high enough (about 20 km/h) to warrant further investigations for the development of wind power generation. There were as of April 1978 11 wind-recording stations in various locations on the Egyptian coasts. Cooperation is underway with the US Agency for International Development and the University of Oklahoma to install a complete experimental wind power station in one of the two locations mentioned above. In **Jordan** the Royal Scientific Society is studying the possibility of producing electricity from wind-powered generators. In **Lebanon** windmills have been in existence for many years, and there are plans for a more important utilization of wind energy in the future, particularly for electricity generation. In **Mauritania** a comprehensive study of the potential for wind energy utilization in the country is being undertaken with the assistance of France. **Morocco's** Ministry of Energy and Mines has been studying the possibility of using wind energy along with solar systems. In **Oman** consideration is being given to installing a pilot plant at a village in Dhofar for the generation of electricity using wind energy. **Somalia's** potential for wind energy use is considered good, and the authorities are seriously contemplating the development of this alternative energy source. Wind velocity at the Berbera, Chisimaio, and Mogadiscio ports is approximately 20 km/h but varies greatly from one place to another in the hinterland. The gradual introduction of windmills and wind-powered generators in the country is given high priority by the government. Plans also include integrated solar/wind/biogas energy systems in rural areas. In **Sudan** the National Research Council has been sponsoring studies undertaken by the Energy Research Institute on the potential for wind energy in the country. The **SAR** has plans to utilize wind energy for electricity generation and water pumping in rural areas. Possible sites for the construction of wind-powered generators include the Lake Quteina, the Palmyra region, and the Aleppo region. In **Tunisia** studies on the possible utilization of wind energy are underway. In **Yemen** wind speed is recorded in the three main cities, but, as in Democratic Yemen, the best potential exists in the region constituting the geographical transition from the highlands of the Arabian Peninsula to the sea.

ELECTRICITY PROJECTIONS

On the basis of the information included in the preceding sections, an estimation is made here of the magnitudes in 1985, 1990, and 2000 of the 13 electricity variables appearing in the energy balance model presented in Table 3.1. Conversion factors, definitions, and other technical information contained in Appendix 1 are used.

Production of Primary Electricity

A synthesis of the country information included in the relevant sections of this chapter results in projections of total Arab primary electricity generation as shown in Table 7.1, compared to 1978 actual data.

To convert these figures into primary fuel input equivalent, country thermal efficiency ratios as projected in the first section of this chapter for each of the 21 Arab states are applied to the corresponding country primary generation forecasts. Adding up the country results, the following estimates are obtained for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

Table 7.1

Projection of Arab Primary Electricity Generation, 1985, 1990, and 2000 (TWh).

	1978	1985	1990	2000
Hydro	14.9	18.5	24.9	41.6
Nuclear	–	4.2	26.8	79.6
Solar, Biomass, Geothermal, Wind	–	0.1	0.6	2.0
Total	14.9	22.8	52.3	123.2

PPE
(in Mtoe) 5.2 7.2 16 32 (21)[6]

It is noted that due to the inherent structure of the energy balance model (see p. 27, identities 8 and 9):

$$PPE = TPE = EPE. \qquad (22, 23)$$

Gross Electricity Generation

A synthesis of the country information included in the first section of this chapter on conventional thermal electricity results in the following Arab world projections for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

Conventional
thermal generation
(in TWh) 52.4 153.0 247.5 527.0

Adding these figures to the corresponding primary generation projections shown above, the following future magnitudes of total electricity generation in the Arab world are obtained for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

Total electricity generation
(in TWh) 67.3 175.8 299.8 650.2
ELG
(in Mtoe) 5.8 15.1 26 56 (24)

A comparison between ELG (2000) and ELG (1977) implies an average annual growth rate of 11.2 percent for ELG between 1977 and 2000. Bearing in mind the 7 percent growth rate of gross domestic product (GDP) projected for the same period in Appendix 8 (see Table A8.3), it follows that the average GDP elasticity of ELG would be equal to 1.6 during the period 1978-2000.

The following econometric relationship is derived for the Arab world, based on data for the period 1960-1977:

$$ELG = 9.6 \times 10^{-5} \times GDP^{1.6} \qquad (\bar{R}^2 = 0.995),$$

where ELG is in thousand toe, GDP is in million 1970 dollars at 1970 prices, and $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom. This relationship estimates the average GDP elasticity of ELG during 1960-1977 at 1.6.

It is, therefore, noteworthy that the independent electricity projections carried out in this chapter imply for 1978-2000 the same average elasticity of Arab power supply relative to GDP that prevailed during 1960-1977.

Solid Fuels, Crude Oil, Petroleum Products, and Natural Gas Fueling Thermoelectricity Plants

A synthesis of the country information included in the first section of this chapter on thermal efficiency and fuel inputs results in projections of thermal electricity fuel inputs in the Arab world as shown in Table 7.2, compared to 1978 actual data.

Table 7.2

Projection of Arab Thermoelectricity Fuel Inputs, 1985, 1990, and 2000 (Mtoe).

	1978	1985	1990	2000	
ESF	0.5	0.6	1	1	(25)
ECP	0.9	2.0	3	4	(4)
EPP	7.6	22.9	32	45	(5)
ENG	8.5	21.9	38	92	(19)
Total	17.5	47.4	76	142	

A comparison of the totals in Table 7.2 with the conventional thermal generation figures above implies the following average thermal efficiency ratios for the Arab world as a whole for 1985, 1990, and 2000, respectively, compared to 1978 (first figure):

[6]The number in parentheses refers to the corresponding step in the sequence of the projections as shown in Chapter 3 (pp. 27-28).

e (in percentage) 26 28 29 32

Waste Heat (or Energy Loss) in Electricity Generation

From the identity (see p. 27, identity 10):

$$W = ESF + ECP + EPP + ENG + EPE - ELG,$$

future magnitudes of waste heat in electricity generation are estimated as follows for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

W (in Mtoe) 16.9 39.5 64 118 (26)

Net Exports of Electricity

This variable does not include future interconnexions between Arab countries since such intra-trade electricity flows cancel out in an integrated Arab world perspective. Thus XEL only concerns net electricity exports from the Arab world as a whole. In this regard, a future scheme is reported by the SAR for a link with Turkey (Aleppo-Aintab) of about 100 MW in a first phase and 300 MW in a second phase [16]. The World Bank has also mentioned a possible link between Turkey and an Iraq-SAR interconnexion. Other possibilities may also exist with respect to Ethiopia and Iran.

Anyway, for the net trade effects of such schemes to be recorded in the energy balance sheet, the corresponding XEL figure should be in excess of ±50 thousand toe (equivalent to a net flow of about 600 GWh, or a capacity of 150-200 MW operating one way) in 1985 and ten times that amount in 1990 and in 2000. This is not likely to be the case. Thus, for XEL quantities (in Mtoe) are less than significant (see notes to Table 3.1) for 1985, 1990, and 2000. (27)

It is noted that due to the inherent structure of the energy balance model (see p. 27, identity 11):

$$XEL = - TEL. \quad (28)$$

Refineries' Own Use of Electricity

Such electricity requirements have already been projected in Chapter 5 (p. 50) as follows for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

REL (in Mtoe) 0.2 0.5 1 2 (12)

Gross Final Consumption of Electricity

From the identity (see p. 27, identity 12):

$$CEL = TEL + ELG - REL,$$

future magnitudes of Arab gross final electricity consumption are estimated as follows for 1985, 1990, and 2000, respectively, compared to 1978 actual data (first figure):

CEL (in Mtoe) 5.6 14.6 25 54 (29)

EIGHT
ENERGY BALANCES OF THE ARAB WORLD, 1985, 1990, AND 2000

With reference to the sequence of the projections in this study as shown in Chapter 3 (see pp. 27-28) it is noted that the first 29 steps have been achieved in Chapters 4 to 7. The present chapter is devoted to the remaining nine steps, of which the first four relate to solid fuels (variables PSF, TSF, XSF, and CSF)[1], while the rest concerns the "Total" column of the energy balance model and can be easily completed using the last five model structural identities (see p. 27).

SOLID FUELS

Solid fuels do not and are not expected to constitute a significant source of energy in the Arab world. They are projected to account for 0.2 percent of Arab primary energy production and about 1 percent of Arab energy requirements during the projection period.

Coal and/or lignite deposits or occurrences have been identified in Algeria, Democratic Yemen, Egypt, Morocco, Oman, Saudi Arabia, Somalia, Sudan, and Yemen. To date, however, only Morocco and, to a much lesser extent, Algeria, have been producing solid fuels in the Arab world. In 1978 Moroccan production reached some 720,000 t, while Algerian output, which had been consistently declining since the 1950s, amounted to 5,000 t. On the other hand, eight Arab countries imported some 1.6 Mt of coal in 1978, with Egypt alone accounting for almost 80 percent of the total.

Prospects for solid fuels production in the Arab world are confined to Algeria, Egypt, Morocco, and Yemen. Morocco's output is projected to rise by an average of 3 percent per annum to about 1.4 Mt in 2000. The Egyptian authorities expect production from the Maghara region in the north-central Sinai to increase from 300,000 t in the early 1980s to 1 Mt in the late 1990s. As for Algeria and Yemen, their combined output would not exceed 0.2 Mt by the turn of the century.

Consumption of solid fuels in the Arab world averaged 2.3 Mt during 1975-1978, 95 percent of which was accounted for by Algeria, Egypt, and Morocco. Thirty percent of the total was burnt in thermal power generation plants, while the rest was used in iron and steel production and other industries. It is projected that Egypt's and Morocco's domestic requirements will grow at an average annual rate of 4 percent during the projection period, whereas the rest of Arab consumption will stagnate around 0.3 Mt.

Two other sources of energy are also included in this study under solid fuels, namely, fuelwood and charcoal. These are widely used in many Arab countries. In Sudan alone, present annual consumption reaches 14 Mt of fuelwood cut. Another important consumer is Somalia, but it is obvious that all Arab countries endowed with natural forests use this type of energy, particularly in rural areas. It is estimated that some 1.6-1.8 Mtoe worth of fuelwood and charcoal are being pro-

[1] The fifth solid fuels variable, ESF, has been projected in Chapter 7 (see Table 7.2).

Table 8.1

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	2.4	1,172.5	100.1	151.4	7.2		1,433.6
Net energy exports (–)	1.2	–911.3	–183.3	–63.6		–	–1,157.0
International bunkers (–)	–	–	–28.7				–28.7
Total primary energy requirements	3.6	261.2	–111.9	87.8	7.2	–	247.9
Electricity generation	–0.6	–2.0	–22.9	–21.9	–7.2	15.1	–39.5
Refineries		–259.2	249.7	–5.7		–0.5	–15.7
Gross final consumption	3.0	–	114.9	60.2		14.6	192.7
				1990			
Primary energy production	3	1,295	107	239	16		1,660
Net energy exports (–)	1	–893	–257	–113		–	–1,262
International bunkers (–)	–	–	–33				–33
Total primary energy requirements	4	402	–183	126	16	–	365
Electricity generation	–1	–3	–32	–38	–16	26	–64
Refineries		–399	384	–12		–1	–28
Gross final consumption	3	–	169	76		25	273
				2000			
Primary energy production	4	1,431	138	382	32		1,987
Net energy exports (–)	1	–702	–432	–147		–	–1,280
International bunkers (–)	–	–	–40				–40
Total primary energy requirements	5	729	–334	235	32	–	667
Electricity generation	–1	–4	–45	–92	–32	56	–118
Refineries		–725	694	–28		–2	–61
Gross final consumption	4	–	315	115		54	488

Notes:

1. A dash (–) indicates nil quantities or figures below 0.05 Mtoe in 1985 and below 0.5 Mtoe in 1990 and in 2000.
2. A blank means that the corresponding item is not applicable.

duced and consumed in the Arab world, and this amount is likely to be more or less maintained in the future.

In the light of the above, production and consumption of solid fuels (inclusive of fuelwood and charcoal) in the Arab world are projected to be as follows for 1985, 1990, and 2000, respectively:

PSF (in Mtoe) 2.4 3 4 (30)[2]

TSF (in Mtoe) 3.6 4 5 (31)

From the identity (see p. 27, identity 13):

$$XSF = PSF - TSF,$$

future magnitudes of Arab net exports of solid fuels (which are actually net imports, because of their

[2] The number in parentheses refers to the corresponding step in the sequence of the projections as shown in Chapter 3 (pp. 27-28).

Table 8.2

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (Mboe/d).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.05	23.78	2.03	3.07	0.15		29.08
Net energy exports (–)	0.02	–18.48	–3.72	–1.29		–	–23.47
International bunkers (–)	–	–	–0.58				–0.58
Total primary energy requirements	0.07	5.30	–2.27	1.78	0.15	–	5.03
Electricity generation	–0.01	–0.04	–0.47	–0.44	–0.15	0.31	–0.80
Refineries		–5.26	5.07	–0.12		–0.01	–0.32
Gross final consumption	0.06	–	2.33	1.22		0.30	3.91
				1990			
Primary energy production	0.1	26.3	2.2	4.8	0.3		33.7
Net energy exports (–)	–	–18.1	–5.2	–2.3		–	–25.6
International bunkers (–)	–	–	–0.7				–0.7
Total primary energy requirements	0.1	8.2	–3.7	2.5	0.3	–	7.4
Electricity generation	–	–0.1	–0.7	–0.7	–0.3	0.5	–1.3
Refineries		–8.1	7.8	–0.3		–	–0.6
Gross final consumption	0.1	–	3.4	1.5		0.5	5.5
				2000			
Primary energy production	0.1	29.0	2.8	7.8	0.6		40.3
Net energy exports (–)	–	–14.2	–8.8	–3.0		–	–26.0
International bunkers (–)	–	–	–0.8				–0.8
Total primary energy requirements	0.1	14.8	–6.8	4.8	0.6	–	13.5
Electricity generation	–	–0.1	–0.9	–1.9	–0.6	1.1	–2.4
Refineries		–14.7	14.1	–0.6		–	–1.2
Gross final consumption	0.1	–	6.4	2.3		1.1	9.9

negative sign) are estimated as follows for 1985, 1990, and 2000, respectively:

XSF (in Mtoe) -1.2 -1 -1 (32)

Future magnitudes of solid fuels fueling Arab thermoelectricity plants were estimated in Chapter 7 (see Table 7.2) as follows for 1985, 1990, and 2000, respectively:

ESF (in Mtoe) 0.6 1 1 (25)

Finally, from the identity (see p. 27, identity 14):

$$CSF = TSF - ESF,$$

future magnitudes of Arab gross final consumption of solid fuels are estimated as follows for 1985, 1990, and 2000, respectively:

CSF (in Mtoe) 3 3 4 (33)

PROJECTED ENERGY BALANCES OF THE ARAB WORLD

The projected energy balances of the Arab world can now be completed using the last five model structural identities (see p. 27):

Table 8.3 .

Projected Energy Balances of the Arab World, 1985, 1990, and 2000 (EJ).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.10	49.09	4.19	6.34	0.30		60.02
Net energy exports (–)	0.05	–38.15	–7.67	–2.66		–	–48.43
International bunkers (–)	–	–	–1.20				–1.20
Total primary energy requirements	0.15	10.94	–4.68	3.68	0.30	–	10.39
Electricity generation	–0.03	–0.09	–0.96	–0.92	–0.30	0.64	–1.66
Refineries		–10.85	10.45	–0.24		–0.02	–0.66
Gross final consumption	0.12	–	4.81	2.52		0.62	8.07
				1990			
Primary energy production	0.1	54.2	4.5	10.0	0.7		69.5
Net energy exports (–)	–	–37.4	–10.8	–4.7		–	–52.9
International bunkers (–)	–	–	–1.4				–1.4
Total primary energy requirements	0.1	16.8	–7.7	5.3	0.7	–	15.2
Electricity generation	–	–0.1	–1.3	–1.6	–0.7	1.1	–2.6
Refineries		–16.7	16.1	–0.5		–	–1.1
Gross final consumption	0.1	–	7.1	3.2		1.1	11.5
				2000			
Primary energy production	0.2	59.9	5.8	16.0	1.3		83.2
Net energy exports (–)	–	–29.4	–18.1	–6.2		–	–53.7
International bunkers (–)	–	–	–1.7				–1.7
Total primary energy requirements	0.2	30.5	–14.0	9.8	1.3	–	27.8
Electricity generation	–0.1	–0.1	–1.9	–3.8	–1.3	2.3	–4.9
Refineries		–30.4	29.1	–1.2		–0.1	–2.6
Gross final consumption	0.1	–	13.2	4.8		2.2	20.3

$$P = PSF + PCP + PGL + PNG + PPE$$
$$X = XSF + XCP + XPP + XNG + XEL$$
$$B = BNK$$
$$TER = TSF + TCP + TPP + TNG + TPE + TEL$$
$$GFC = CSF + CPP + CNG + CEL,$$

where all the variables appearing on the right hand side have already been estimated in Chapters 4 to 7 and earlier in this chapter. Thus, the following estimates (in Mtoe) are derived for 1985, 1990, and 2000, respectively:

P	1,433.6	1,660	1,987	(34)
X	1,157.0	1,262	1,280	(35)
B	28.7	33	40	(36)
TER	247.9	365	667	(37)
GFC	192.7	273	488	(38)

All of the 38 steps of the sequence of the projections as shown in Chapter 3 (see pp. 27–28) have now been achieved. The results are presented in Tables 8.1, 8.2, and 8.3 in the form of energy balance sheets for the years 1985, 1990, and 2000.

They are not only expressed in million metric tons of oil equivalent (Mtoe, Table 8.1) but also in million barrels per day of oil equivalent (Mboe/d, Table 8.2)[3] and in exajoules (EJ, Table 8.3),[4] for easy reference.

GEOGRAPHICAL BREAKDOWN OF RESULTS

A breakdown by country of the projected energy balances of the Arab world presented in Tables 8.1–8.3 goes beyond the methodological scope of this study. This is essentially true for seven of the 38 variables of the energy balance model, which are estimated for the Arab world as a whole mainly on the basis of an Arab common policy for both crude production and refining.

For the sake of illustration, however, a geographical breakdown of the results is attempted in Appendix 9. For this purpose, the Arab world is divided into ten countries or groups of countries, as shown in Table 8.4.

Table 8.4

Geographical Breakdown of the Arab World by Countries or Groups of Countries

Arab Africa
- Algeria
- Egypt
- Libyan Arab Jamahiriya
- Other Arab Africa (Djibouti, Mauritania, Morocco, Somalia, Sudan, and Tunisia)

Arab Middle East
- Iraq
- Kuwait
- Saudi Arabia
- United Arab Emirates
- Other Arabian Peninsula (Bahrain, Democratic Yemen, Oman, Qatar, and Yemen)
- Other Arab Middle East (Jordan, Lebanon, and Syrian Arab Republic)

Appendix 9 presents the energy balances of each country/grouping for 1985, 1990, and 2000, as well as the method used to derive them. Due to the limitations of the breakdown method, however, the country/grouping projections should be considered with caution.

[3] To obtain Mboe/d, Mtoe are divided by 49.306 for 1985, 49.330 for 1990, and 49.344 for 2000. The conversion factors are compiled using an average specific gravity for Arab crude estimated on the basis of an illustrative breakdown by country of future Arab crude oil production as projected in Chapter 4 (see Appendix 9).

[4] 1 EJ = 10^6 TJ = 23.885 Mtoe (see Appendix 1, p. 103, footnote 3).

NINE
THE WORLD OUTLOOK: CRISIS OR COOPERATION?

The projections carried out in the earlier chapters have mainly been founded on the assumption that the output of crude petroleum in the Arab world would be determined by an Arab long-term production policy that is based largely on consideration of its own present and future crude reserve position rather than on an analysis of the world market for oil. Since the Arab countries supply such a large proportion of the oil consumed in the world, and since energy has an important influence on global economic growth, it is clearly desirable to examine the other side of the equation by considering future world demand for energy in general and for oil in particular. The question whether Arab energy and oil exports as projected in this study would be adequate to meet world requirements depends very largely on the vigorousness of the policies adopted by OECD governments to expand energy production and reduce energy requirements per unit of their GDP, as well as on the level of GDP.

This study is about the Arab world; therefore, a full-scale investigation of future economic growth in the OECD area and of government policy measures that might be taken to stimulate production of energy and economy in its use goes beyond the scope of the present projections. Besides, ECWA is not the body to undertake any sort of authoritative analysis of this kind. However, the link between the Arab world and the rest of the world is of paramount importance, and the task will only be complete when this link is established. This could ideally be achieved by a "world energy council," but in the absence of such a body the problem can be best approached by a continuous dialogue between consumers and producers.

To provide a basis for such a dialogue, this final chapter briefly discusses the principles involved and attempts to integrate the Arab world projections undertaken in the earlier chapters in a purely illustrative picture of future world primary energy and oil supply and demand. For any such dialogue to be meaningful, however, the figures in this illustrative picture relating to non-Arab countries need to be replaced by authoritative forecasts supplied by the relevant parties.

METHODOLOGY

The time horizon chosen for this exercise is 1990. This is because looking to an earlier target year, say 1985, would go against the raison d'être of the exercise, which is to examine what actions and policy measures should be adopted very early in the 1980s to influence the future, and there are long lead times on both the supply side and the demand side. For example, the potential output of nuclear power in any given future year depends on the capacity of the generating plants completed during an intervening period, which has to be of at least seven to eight years, from the time of deciding on the site of the envisaged plant to the time of its commissioning; and the potential demand for energy in any given future year (both in quantity and type of fuel) is much influenced by the growth of capacity in the energy-using industries, by the energy conservation measures that will be enforced in many spheres (thermal insulation, size of cars, etc.), and by changes in the public attitude toward saving energy. On the other hand, looking to a time horizon far beyond

1990, say to 2000, would not be very helpful for policy planning due to the compounded uncertainties involved. Moreover, the outcome of actions and policy measures taken in the 1980s would certainly need to be taken into account in such longer-term forecasts.

The position in 1990 will be enormously influenced by what has happened in all years between now and 1990. This is because of the long lead times involved. The basic assumptions in this exercise, therefore, must relate to conditions during the whole of the intervening period, i.e., the 1980s.

What happens during the intervening period is largely influenced, on the one hand, by market reactions to the position of the economy, such as GDP growth and the relative price of energy, and, on the other hand, by government policy. The basic assumptions will have to deal with both of these.

In the light of the above, this exercise adopts:

1. One assumption about economic growth in the OECD area during the 1980s.
2. Two alternative assumptions concerning the "vigour" with which OECD governments will pursue their energy policies during the 1980s.
3. Two alternative assumptions relating to the evolution of the price of oil in real terms during the 1980s.

Obviously, there are interactions between growth, government policy, and price. A change in policy may affect the level of GDP, but some actions would tend to raise it, others to lower it, so that the final outcome may prove that the interaction is not too important. The same applies for a change in the real price of oil (that is, a smooth increase that would not impair economic performance); it might have limited recessionary effects, but it would also help stimulate energy production, so that its overall effect on GDP is not too clear. That is why it does not appear to be imperative to change such a priority objective as GDP growth and take two alternative assumptions for economic performance; rather, it seems logical and acceptable to adopt a single growth assumption with each of the four policy/price variants.

The quantitative picture presented in Table 9.1 (see p. 99) is based, for the Arab world, on the findings of this study as summarized in Table 8.2, and, for the rest of the world, on a critical analysis of a great number of existing energy and oil supply and demand projections (listed in Appendix 10), and bearing in mind the basic assumptions outlined above and explicited in the following section.

The illustrative figures shown in Table 9.1 are in no sense forecasts of what will happen. They are not necessarily even conditional forecasts of what would happen under the basic assumptions, because these assumptions may lead to a position in which world energy and/or oil supply and demand are seriously out of balance. It should be emphasized that the figures would in principle represent the sum of the amounts that each country would wish to produce and consume in 1990, given the capacity it would have built up and the policies it would have implemented in the intervening years on the basis of the broad key assumptions on growth, policy, and price adopted in this exercise.

BASIC ASSUMPTIONS

OECD Area Economic Growth Rate

A judicious choice of the future growth path ranks as a high-priority objective for OECD governments. The economic growth rate should not be set too high, not only because it might create an unmanageable shortage of energy, but also because of constraints that have nothing to do with energy shortages, such as demand management policies, inflation problems, etc. It should not be set too low, not only because of its far-reaching consequences on the world economy, but also because governments cannot afford to take unpopular decisions with adverse effects on employment and living standards simply on grounds of containing inflation and solving balance of payments problems.

Three factors can limit growth, if all else were held equal: energy shortages, real oil price increases, and inflation. These factors interact through government policies, but they can exist independently from one another. Energy requirements per unit of GDP are a structural characteristic of the economy that evolves quite slowly, so that limited energy supply availabilities will affect growth. An increase in the real price of oil, despite its quite modest relative inflationary effect on the economy, seems to have a psychological impact on governments, which automatically start contemplating measures to contain domestic demand, and, hence, to restrain growth. As for inflation, it has been persistent in the Western economies since the Second World War, but as of the early 1970s growing sociopolitical pressures, balance of payments tensions, and monetary disorders have combined to maintain it at high levels, thereby inhibiting economic growth, which is estimated for the whole OECD area at about 2.7 percent per annum between 1973 and 1980, compared with 4.8 percent between 1960 and 1973.

For the 1980s, it is logical to adopt for the OECD area a growth rate that would be plausible if energy were not the major constraint, just as the Arab crude oil production policy considers primarily producers' interests. It seems now to be recognized that a rather modest growth rate is likely to be achieved, for reasons relating to structural constraints other than energy, as explained above. This exercise, therefore, assumes an average annual growth rate of 3 percent for the OECD area between 1980 and 1990.

There is no harm, of course, in assuming a higher growth rate, say 5 percent, to study the possible implications for energy supply and demand, but it would be a rather academic exercise. If, for example, it led to the conclusion that there would be a large energy shortage unless the most drastic measures were taken to raise considerably the output of nuclear electricity and to curb demand by banning oil and gas use in power generation and by halting any increase in private motoring, one would not expect such unpopular policies to be adopted unless they were also shown to be necessary with a 3 percent growth rate. Besides, even if these drastic measures were to be taken, a 5 percent real growth target would not be likely to be attained because of inflation.

OECD Government Energy Policies

Such government policies are generally of two broad kinds:

1. Measures to promote production of primary energy (oil and nonoil), which can take numerous forms. For example, government funds may be provided for research and development and also for actual investment in large ventures that may or may not be profitable (coal mines, nuclear power, etc.) but have to be undertaken despite the uncertainties. Governments may also play an important role through issuing licenses or concessions to private producers (which may crucially affect new projects for energy production), through adapting environmental regulations, through lifting domestic oil and gas price controls designed to help consumers, etc.

2. Measures to reinforce energy conservation (especially oil). Actions in this sphere may include, for example, raising through taxation the price paid by users, subsidizing fuel-saving schemes, setting regulations that enforce the production of more economical motorcars or the building or better insulated houses, etc. Governments may also play an important role in reducing oil consumption by securing a switch of fuel usage away from oil, either through price increase or through administrative action.

This exercise adopts two alternative assumptions about the "vigour" with which OECD governments would pursue their energy policies during the 1980s, one moderate or restrained, and one forceful or vigorous.

Real Price of Oil

The oil price received by producers in the years up to 1990 will affect their incentive to develop new oil fields and to extract more oil from existing ones. Expectations about future prices are in some ways even more important than the present price. This exercise, therefore, explicitly includes an assumption about how the real price of oil would move in the 1980s, with the tacit understanding that producers would receive the world price (adjusted for transport costs), treating any aberrations (such as any continuing controls in the USA) as a negative element under "government policies" (see policy 1. above).

The world price of oil will also have an effect on the incentive to produce alternative forms of energy and to introduce fuel economy devices. In the latter case, however, the price paid by the final consumer is more relevant, and this is affected by government taxation, which can legitimately be treated under "policies" (see policy 2. above).

A great number of projections (listed in Appendix 10), including the WAES study [2] (see p. 30 and Appendix 5), reject the idea of a rising oil price in real terms before 1985 because they reckon that there would be no unmanageable shortage (on the assumption that OPEC countries would be willing to produce near sustainable capacity if the demand was there). This is not acceptable here because the Arab production policy adopted in this study (which virtually means an OPEC policy) implies that an excess sustainable capacity averaging 4 Mb/d would be maintained in the Arab world during the 1980s (see p. 41). Besides, OPEC countries seemed by mid-1980[1] to have agreed on a formula for gradually increasing the real price of oil by linking it, *inter alia,* to economic growth in OECD countries.

This exercise, therefore, adopts two alternative assumptions about the evolution of the price of oil in real terms between 1980 and 1990, one constant at today's level[2] and one gently rising by 2 percent per annum, on the average.

ILLUSTRATIVE PICTURE OF WORLD ENERGY AND OIL SUPPLY AND DEMAND, 1990

On the basis of the methodology presented in the first section of this chapter and the basic assumptions explained in the second section, this section shows a purely illustrative picture for 1990 of the supply and demand for primary energy and oil in the world divided into the following major groupings:

1. OECD area, the major consumer.
2. Arab world, the major producer.
3. Non-Arab OPEC countries.
4. Rest of the world outside centrally-planned economies.
5. Centrally-planned economies of Asia and of Europe.

The results of the exercise are presented in Table 9.1. Illustrative figures are shown for the following four cases:

1. Restrained OECD government energy policies and constant real oil price (the restrained policy–constant price case, for short).
2. Restrained OECD government energy policies and real oil price rising by 2 percent per annum (the restrained policy–rising price case, for short).
3. Vigorous OECD government energy policies and constant real oil price (the vigorous policy–constant price case, for short).
4. Vigorous OECD government energy policies and real oil price rising by 2 percent per annum (the vigorous policy–rising price case, for short).

Moreover, each of the four cases gives figures for world total primary energy supply and demand, on the one hand, and for world oil supply and demand, on the other.

Finally, recall that:

1. The overall GDP of the OECD area is assumed to grow at an average annual rate of 3 percent between 1980 and 1990.

2. The basic assumptions about government policies and oil price relate to the whole of the intervening period, i.e., the whole of the 1980s.

3. The figures are in no sense forecasts; they are not even conditional forecasts of what would happen under the basic assumptions,

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[1] OPEC extraordinary meeting in Taef (Saudi Arabia) in May 1980. A decision to this effect was expected to be taken at a subsequent OPEC summit meeting.

[2] At the beginning of 1980 the average OPEC price, weighted by individual member country production volumes, stood at about $29/b. The price of the "marker" crude was $26/b.

Table 9.1

Illustrative Picture of World Primary Energy and Oil Supply and Demand[a], 1990 (Mboe/d).

OECD Government Energy Policies, 1980–1990:	Restrained				Vigorous			
Real Price of Oil, 1980–1990:	Constant		Rising 2 Percent Per Annum		Constant		Rising 2 Percent Per Annum	
	Total Energy	Oil	Total Energy	Oil	Total Energy	Oil	Total Energy	Oil
OECD								
Supply	70	16	74	19	74	17	77	20
Demand	108	52	106	50	105	49	103	47
Surplus (+) or Deficit (–)	–38	–36	–32	–31	–31	–32	–26	–27
Arab World								
Supply	33	28	33	28	33	28	33	28
Demand	8	5	8	5	8	5	8	5
Surplus (+) or (Deficit (–)	25	23	25	23	25	23	25	23
Non-Arab OPEC[b]								
Supply	14	11	14	11	14	11	14	11
Demand	9	7	9	7	9	7	9	7
Surplus (+) or Deficit (–)	5	4	5	4	5	4	5	4
Rest of WOCPE[c]								
Supply	20	9	22	11	20	9	22	11
Demand	19	8	20	9	19	8	20	9
Surplus (+) or Deficit (–)	1	1	2	2	1	1	2	2
CPEs[d]								
Surplus (+) or Deficit (–)	–	–	–	–	–	–	–	–
World								
Surplus (+) or Deficit (–)	–7	–8	–	–2	–	–4	6	2
Memorandum Item								
OPEC								
Supply	45	38	45	38	45	38	45	38
Demand	14	10	14	10	14	10	14	10
Surplus (+) or Deficit (–)	31	28	31	28	31	28	31	28

[a]Demand includes bunkers.
[b]Ecuador, Gabon, Indonesia, Iran, Nigeria, and Venezuela.
[c]Rest of the world outside centrally-planned economies.
[d]Centrally-planned economies of Asia (China, Democratic People's Republic of Korea, Mongolia, and Viet Nam) and of Europe (Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, and USSR).

Assumptions:

1. OECD area GDP growth rate, 1980–1990: 3 percent per annum.
2. Arab world energy and oil supply and demand, 1990: from Table 8.2.

Note:

A dash (–) indicates nil or negligible quantities.

since they mostly lead to imbalances in world supply and demand, which cannot happen in the real world.

4. The amounts shown reflect country wishes regarding energy and oil production and consumption in 1990, under certain conditions.

5. This exercise only provides a basis for a necessary, continuous dialogue between consumers and producers, for the usefulness of which the non-Arab figures shown here should

be replaced by authoritative forecasts supplied by the relevant parties.

CONCLUSIONS

An examination of Table 9.1 calls for the following remarks:

The world supply and demand situation in 1990 would not seem to be as alarming for total primary energy as it is for oil. In fact, three cases out of four show a balance or even a surplus in total energy. As for oil, the outlook changes significantly, and three cases out of four show a global deficit. This discrepancy between the total energy position and the oil position implies that future fuel-mix availabilities would not match the preferred fuel-mix pattern. The gap is most pronounced for oil, where a deficit ranging from 3 to 11 percent of world demand is shown in the first three cases. In this connexion, it is worth recalling the large impact that a shortage of 3 percent in oil supply availabilities (2 Mb/d) had on oil prices and markets in 1979 (see p. 35).

Accordingly, the vigorous policy—rising price case seems to be the only one out of the four in which it can be reasonably assumed that the world would not face a shortage of oil and energy in 1990.

Changing the assumptions about government policies and oil prices obviously influences primarily the supply and demand figures for the OECD area. Between the restrained policy—constant price case and the vigorous policy—rising price case, OECD energy supply would expand by 10 percent (oil supply by 25 percent), energy demand would be reduced by 5 percent (oil demand by 10 percent), so that 32 percent (25 percent) of the OECD deficit in energy (in oil) would be eliminated.

The Arab world and the rest of the OPEC countries would not be affected to any significant extent by a change in OECD policies or in oil prices, as far as their energy and oil supply and demand situation is concerned. This is understandable because the Arab world's future energy balance is projected in the previous chapters independently from the basic assumptions of this exercise, and because other OPEC countries would probably tend to follow suit, bearing in mind that the majority would be producing to capacity.

The picture for the rest of the world outside the centrally-planned economies would not be significantly influenced by a change in OECD government policies. A rising oil price, however, would favorably affect supply for obvious reasons, but it would also relieve a certain amount of suppressed demand, thereby directing about one-half of the production increases to domestic use, despite the price increase. The other half would be exported, thus doubling the overall surplus of these countries.

As for the centrally-planned economies, supply and demand would be in balance under the four cases, in the sense that a change in the price assumption might affect supply and demand by equal amounts.

APPENDIX ONE
ENERGY BALANCES OF THE ARAB WORLD, 1960 - 1978

The usefulness of basic energy data can be considerably improved by expressing them in a single common unit suitable for a number of uses, such as the estimation of total energy requirements, projections of energy supply and demand, and the study of substitution and conservation. The approach adopted here in converting the basic data to a common unit is sometimes known as the "partial substitution model." In this model all primary and secondary (derived) fossil fuels are expressed in terms of the quantity of oil that gives the same amount of heat under ideal conditions ("oil equivalent"); primary electricity is expressed in terms of the hypothetical amount of oil that would be needed to produce the same amount of electricity in existing conventional thermal power plants.[1]

The common energy unit adopted here is the metric ton of oil equivalent (toe). A ton of oil equivalent is defined as 10 million kilocalories (1 toe = 10^7 kcal), a convenient measure, although it is somewhat below the average heat content of crude oil. An alternative unit that is also commonly used is the barrel per day of oil equivalent (boe/d). One boe/d is approximately equal to 50 toe.[2] Yet another energy unit of more recent use is the terajoule (TJ). One TJ is approximately equal to 24 toe.[3]

Table A1.1 lists the conversion factors used in tabulating the energy balances. Table A1.2 presents the energy balances of the Arab world from 1960 through 1978. The table is laid out so that the columns contain the various types of fuels and the rows contain the different origins and uses.

The specific items in the columns (types of fuels) are:

1. Solid fuels, both primary (hard coal, lignite, peat) and derived (coke, briquettes).

2. Crude petroleum.

---

[1] Primary fuels are hard coal, lignite and peat (solid fuels), crude petroleum, natural gas liquids, natural gas, and primary electricity (hydro, nuclear, solar, geothermal, wind, biomass, etc.). Secondary or derived energy consists of the fuels obtained by transformation of primary fuels, such as coke, briquettes, and manufactured gases (derived from solid fuels), all refinery petroleum products (derived from crude petroleum), and conventional thermal electricity.

[2] In fact, the exact conversion is as follows, for the average barrel:

$$1 \text{ boe/d} = 365 \times 0.860/6.2898 \text{ toe} = 49.906 \text{ toe},$$

where: 365 is the number of days in a year, 6.2898 the number of barrels for one cubic metre (volume), and 0.860 the world average specific gravity of crude oil. Specific gravity varies with the type of crude; country averages can be as low as 0.784 (New Zealand) and as high as 0.970 (Sweden). For the Arab world as a whole average specific gravity (weighted by country crude output data) stood at 0.849 in 1979.

[3] In fact, the exact conversion is:

$$1 \text{TJ} = 23.885 \text{ toe}.$$

3. Petroleum products: refinery petroleum products and natural gas liquids (NGL). Refinery products consist of energy products (LPG from refineries, aviation and motor gasolenes, kerosene and jet fuels, distillate and residual fuel oils) and nonenergy products (naptha, white spirit, paraffin wax, lubricating oils, road oil, bitumen, petroleum coke). NGL mainly comprise NGN (liquid hydrocarbons such as pentanes, hexane, heptane, and octane recovered from "wet" natural gas), LPG extracted from natural gas (mainly propane and butanes recovered from natural gas by liquefaction under relatively mild operating conditions), and PC (liquid hydrocarbons condensed from wet natural gas).

4. Natural gas and manufactured gases (gas works and coke-oven gases). Natural gas data exclude gas used for repressuring and reinjection—as well as gas flared, vented, or otherwise wasted—and shrinkage due to processing for the extraction of NGL. After the extraction of NGL, the main constituent of natural gas, methane, can be liquefied at atmospheric pressure by cooling to about -160°C (-256°F) and is then known as LNG.

5. Primary electricity (hydro, nuclear, solar, geothermal, wind, biomass, etc.): fuel input required to produce the equivalent amount of primary electricity from conventional thermal (fossil-fueled) power plants. Primary electricity other than hydropower is indicated here for the record only, since no such production existed in the Arab world during the period 1960–1978.

6. Electricity: total electricity generation in final consumption (in row 7), and trade in electricity (in rows 2 and 3) counted at the same heat value as electricity in final consumption.

7. Total: algebraic total of columns 1 to 6. This column shows in particular total domestic

Table A1.1

Average Conversion Factors

Solid Fuels	1 t = 0.70	toe
Liquid Fuels		
Crude petroleum	1 t = 1.03	toe
Liquefied natural gas (LNG)	1 t = 1.31	toe
Liquefied petroleum gas (LPG)	1 t = 1.18	toe
Natural gasolene (NGN)	1 t = 1.16	toe
Plant condensate (PC)	1 t = 1.15	toe
Gasolenes and naptha	1 t = 1.13	toe
Kerosene and jet fuels	1 t = 1.11	toe
Fuel oils	1 t = 1.05	toe
Nonenergy petroleum products other than naptha (weighted average)	1 t = 0.95	toe
Gaseous Fuels[a]		
Natural gas (dry)	1,000 cu.m = 0.93	toe[b]
Propane and butanes	1,000 cu.m = 2.62	toe
Pentanes and higher	1,000 cu.m = 3.89	toe
Electricity		
In final consumption	1 GWh = 86.10	toe
In primary production	1 GWh = 86.10/e	toe[c]

[a]The volume ratio of LNG to dry natural gas is approximately 590 to 1; the ratio of LPG to gaseous propane and butanes is approximately 240 to 1; the ratio of NGN to gaseous pentanes and higher is approximately 180 to 1.

[b]Except for Algeria and Tunisia, where the conversion factors are 0.95 and 1.10, respectively.

[c]*e* is the average efficiency ratio of conventional thermal power plants. Estimates of *e* for the Arab world as a whole have ranged from 23 to 26 percent during the period 1960–1978. This means that only 23 to 26 percent of the energy in the fuel burnt has been transformed into electricity output, the majority of the energy loss (or waste heat) accruing to the conversion of heat energy into mechanical energy to turn generators. The greater part of this energy loss is inherent in the process, by the second law of thermodynamics.

energy requirements (excluding international bunkers) in row 6 and gross final consumption in row 10.

The specific items in the rows (origins and uses) are:

1. Primary energy production: domestic production of primary fuels.

2. Imports (+) of primary and derived forms of energy.

3. Exports (-) of primary and derived forms of energy.

4. Bunkers (-): fuels supplied to ships and aircraft in international transportation (treated as exports).

5. Changes in stocks (±) at producers and importers. Additions to stocks are negative and withdrawals from stocks are positive.

6. Total energy requirements (TER): algebraic total or rows 1 to 5. TER are equal to the domestic production of primary energy less the net exports of primary and derived energy (including bunkers) and adjusted for stocks changes. Domestic production of secondary energy is not included in TER to avoid double counting. This is because refinery petroleum products, for example, are produced from crude oil which is already included in TER under crude petroleum (column 2).

7. Electricity generation. Columns 1 to 5 contain fuel inputs (and fuel input equivalent in the case of primary electricity, under column 5) as negative entries. Gross electricity produced for consumption (including power stations' own consumption and all plant, transmission, and distribution losses) appears as a positive quantity under electricity (column 6). The figure in the "Total" column is counted as being the overall waste heat (see Table A1.1, footnote c), although some of it may be used for heating and other purposes. Consumption from autogeneration and production by industry are also included in this category.

8. Refineries. All forms of energy going through refineries, both for transformation into derived (secondary) energy and for use as refinery fuel, are shown as negative quantities under crude petroleum (column 2), natural gas (column 4) and electricity (column 6). The output of all refined products appears under petroleum products (column 3) as a positive figure. Refineries' own energy use and losses are recorded in the "Total" column.

9. Statistical differences. This category serves three purposes. First, it contains unexplained statistical differences for individual fuels, appearing in the original energy data source and also resulting from estimations made for certain items in the previous two rows (see below). Second, it is used for transferring those NGL that enter refineries from column 3, where they appear as primary supply, to column 2. Thus, they are shown in this row as negative under petroleum products (column 3) and positive under crude petroleum (column 2). Third, naptha backflows from the petrochemical industry to refineries for blending are included as positive statistical differences under crude petroleum (column 2).

10. Gross final consumption: algebraic total of rows 6 to 9. This is the total amount of solid fuels, petroleum products, natural gas and manufactured gases, and electricity that are used by the various economic sectors for energy and nonenergy purposes. It is termed "gross" final consumption because it also includes the primary energy use by energy-producing industries, plus the energy loss in the production, processing, conversion, and transportation of fuels (except for electricity generation heat losses and refineries' own uses and losses, accounted for in rows 7 and 8, respectively). Thus, for example, natural gas use in crude oil production and transportation, as well as losses in the processing of LNG and NGL, are included —and so are power stations' own electricity use and plant, transmission, and distribution losses.

The energy balances of the Arab world for the years 1960 to 1978, which are presented in Table A1.2, were compiled mainly on the basis of country data appearing in issues nos. 19, 20, 21, and 22 of United Nations' *World Energy Supplies* (WES) [17]. The first issue was used for the preparation of the

Table A1.2

Energy Balances of the Arab World, 1960–1978 (Mtoe)

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
1960							
Primary energy production	0.3	216.8	0.1	1.5	0.7		219.4
Imports (+)	0.5	25.2	9.4	–		–	35.1
Exports (–)	–0.1	–195.8	–25.5	–		–	–221.4
International bunkers (–)	–	–	–12.5				–12.5
Changes in stocks (±)	–	–0.7	–	–			–0.7
Total primary energy requirements	0.7	45.5	–28.5	1.5	0.7	–	19.9
Electricity generation	–0.2	–0.1	–2.0	–0.2	–0.7	0.7	–2.5
Refineries		–45.6	44.1	–1.0		–0.1	–2.6
Statistical differences		0.2	–				0.2
Gross final consumption	0.5	–	13.6	0.3		0.6	15.0
1961							
Primary energy production	0.3	247.4	0.2	1.7	1.0		250.6
Imports (+)	0.5	19.1	8.9	–		–	28.5
Exports (–)	–0.1	–216.1	–27.4	–		–	–243.6
International bunkers (–)	–	–	–13.2				–13.2
Changes in stocks (±)	–	–0.7	–	–			–0.7
Total primary energy requirements	0.7	49.7	–31.5	1.7	1.0	–	21.6
Electricity generation	–0.2	–0.1	–2.1	–0.2	–1.0	0.8	–2.8
Refineries		–49.1	47.4	–1.1		–0.1	–2.9
Statistical differences		–0.5	–0.2				–0.7
Gross final consumption	0.5	–	13.6	0.4		0.7	15.2
1962							
Primary energy production	0.3	282.9	0.3	2.2	1.1		286.8
Imports (+)	0.4	22.5	8.2	–		–	31.1
Exports (–)	–0.1	–248.8	–29.5	–		–	–278.4
International bunkers (–)	–	–	–14.7				–14.7
Changes in stocks (±)	–	0.5	–	–			0.5
Total primary energy requirements	0.6	57.1	–35.7	2.2	1.1	–	25.3
Electricity generation	–0.2	–0.1	–2.3	–0.3	–1.1	0.9	–3.1
Refineries		–54.1	52.2	–1.2		–0.1	–3.2
Statistical differences		–2.9	–0.2				–3.1
Gross final consumption	0.4	–	14.0	0.7		0.8	15.9
1963							
Primary energy production	0.3	325.2	0.6	2.5	1.3		330.0
Imports (+)	0.4	23.4	8.0	–		–	31.8
Exports (–)	–0.1	–289.0	–31.0	–		–	–320.1
International bunkers (–)	–	–	–14.8				–14.8
Changes in stocks (±)	–	–	–	–			–
Total primary energy requirements	0.6	59.7	–37.2	2.5	1.3	–	26.9
Electricity generation	–0.1	–0.1	–2.4	–0.4	–1.3	1.0	–3.3
Refineries		–57.1	55.2	–1.3		–0.1	–3.3
Statistical differences		–2.5	–0.3				–2.8
Gross final consumption	0.5	–	15.3	0.8		0.9	17.5

Table A1.2 (continued)

Energy Balances of the Arab World, 1960–1978 (Mtoe)

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1964			
Primary energy production	0.3	378.4	1.0	3.7	1.4		384.8
Imports (+)	0.5	24.3	6.5	–		–	31.3
Exports (–)	–0.1	–342.0	–31.9	–0.1		–	–374.1
International bunkers (–)	–	–	–16.0				–16.0
Changes in stocks (±)	–	0.3	–	–			0.3
Total primary energy requirements	0.7	61.0	–40.4	3.6	1.4	–	26.3
Electricity generation	–0.1	–0.1	–2.6	–0.6	–1.4	1.1	–3.7
Refineries		–62.6	60.6	–1.4		–0.1	–3.5
Statistical differences		1.7	–0.4				1.3
Gross final consumption	0.6	–	17.2	1.6		1.0	20.4
				1965			
Primary energy production	0.4	422.7	1.5	4.8	1.6		431.0
Imports (+)	0.4	23.5	5.6	–		–	29.5
Exports (–)	–0.1	–378.2	–34.1	–0.8		–	–413.2
International bunkers (–)	–	–	–16.1				– 16.1
Changes in stocks (±)	–	–1.1	–	–			– 1.1
Total primary energy requirements	0.7	66.9	–43.1	4.0	1.6	–	30.1
Electricity generation	–0.1	–0.1	–2.7	–0.8	–1.6	1.2	–4.1
Refineries		–65.7	63.5	–1.4		–0.1	–3.7
Statistical differences		–1.1	–0.7				–1.8
Gross final consumption	0.6	–	17.0	1.8		1.1	20.5
				1966			
Primary energy production	0.4	482.8	2.1	5.9	1.5		492.7
Imports (+)	0.3	24.1	6.2	–		–	30.6
Exports (–)	–0.1	–436.7	–33.7	–0.9		–	–471.4
International bunkers (–)	–	–	–17.4				–17.4
Changes in stocks (±)	–	0.5	–	–			0.5
Total primary energy requirements	0.6	70.7	–42.8	5.0	1.5	–	35.0
Electricity generation	–0.2	–0.2	–2.9	–0.9	–1.5	1.3	–4.4
Refineries		–68.6	66.3	–1.5		–0.1	–3.9
Statistical differences		–1.9	–0.8				–2.7
Gross final consumption	0.4	–	19.8	2.6		1.2	24.0
				1967			
Primary energy production	0.4	508.8	2.5	6.7	1.6		520.0
Imports (+)	0.5	23.2	4.5	–		–	28.2
Exports (–)	–0.1	–461.2	–37.7	–1.1		–	–500.1
International bunkers (–)	–	–	–16.8				–16.8
Changes in stocks (±)	–	–2.2	–	–			–2.2
Total primary energy requirements	0.8	68.6	–47.5	5.6	1.6	–	29.1
Electricity generation	–0.3	–0.2	–3.0	–1.0	–1.6	1.4	–4.7
Refineries		–71.5	69.1	–1.6		–0.1	–4.1
Statistical differences		3.1	–0.9				2.2
Gross final consumption	0.5	–	17.7	3.0		1.3	22.5

Table A1.2 (continued)

Energy Balances of the Arab World, 1960-1978 (Mtoe)

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1968			
Primary energy production	0.3	610.5	4.2	8.9	2.0		625.9
Imports (+)	0.6	19.9	5.0	–		–	25.5
Exports (–)	–0.1	–545.7	–44.7	–1.3		–	–591.8
International bunkers (–)	–	–	–13.8				–13.8
Changes in stocks (±)	–	0.7	–	–			0.7
Total primary energy requirements	0.8	85.4	–49.3	7.6	2.0	–	46.5
Electricity generation	–0.3	–0.2	–2.9	–1.2	–2.0	1.6	–5.0
Refineries		–74.4	71.9	–1.7		–0.1	–4.3
Statistical differences		–10.8	–1.4				–12.2
Gross final consumption	0.5	–	18.3	4.7		1.5	25.0
				1969			
Primary energy production	0.3	672.1	4.7	10.6	2.5		690.2
Imports (+)	0.6	22.2	6.7	–		–	29.5
Exports (–)	–0.1	–618.9	–47.4	–1.6		–	–668.0
International bunkers (–)	–	–	–14.1				–14.1
Changes in stocks (±)	–	2.0	–	–			2.0
Total primary energy requirements	0.8	77.4	–50.1	9.0	2.5	–	39.6
Electricity generation	–0.2	–0.2	–2.8	–1.5	–2.5	1.8	–5.4
Refineries		–79.2	76.5	–1.8		–0.2	–4.7
Statistical differences		2.0	–1.6				0.4
Gross final consumption	0.6	–	22.0	5.7		1.6	29.9
				1970			
Primary energy production	0.3	743.6	4.9	11.8	2.8		763.4
Imports (+)	0.7	24.7	6.4	–		–	31.8
Exports (–)	–	–677.2	–57.5	–1.5		–	–736.2
International bunkers (–)	–	–	–17.6				–17.6
Changes in stocks (±)	–	0.6	–	–			0.6
Total primary energy requirements	1.0	91.7	–63.8	10.3	2.8	–	42.0
Electricity generation	–0.2	–0.3	–2.9	–1.6	–2.8	1.9	–5.9
Refineries		–95.1	91.9	–2.1		–0.2	–5.4
Statistical differences		3.7	–1.3				2.4
Gross final consumption	0.8	–	23.9	6.6		1.7	33.0
				1971			
Primary energy production	0.4	787.4	4.8	13.9	3.0		809.5
Imports (+)	0.6	21.5	6.8	–		–	28.9
Exports (–)	–	–715.8	–50.8	–1.5		–	–768.1
International bunkers (–)	–	–	–22.8				–22.8
Changes in stocks (±)	–	–2.0	–	–			–2.0
Total primary energy requirements	1.0	91.1	–62.0	12.4	3.0	–	45.5
Electricity generation	–0.2	–0.3	–3.3	–2.0	–3.0	2.1	–6.7
Refineries		–95.5	92.3	–2.1		–0.2	–5.5
Statistical differences		4.7	–1.2				3.5
Gross final consumption	0.8	–	25.8	8.3		1.9	36.8

Table A1.2 (continued)

Energy Balances of the Arab World, 1960–1978 (Mtoe)

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1972			
Primary energy production	0.4	839.1	5.9	18.3	3.0		866.7
Imports (+)	0.6	21.3	6.8	–		–	28.7
Exports (–)	–	–774.3	–43.9	–1.7		–	–819.9
International bunkers (–)	–	–	–24.3				–24.3
Changes in stocks (±)	–	3.5	–0.3	–			3.2
Total primary energy requirements	1.0	89.6	–55.8	16.6	3.0	–	54.4
Electricity generation	–0.2	–0.4	–3.6	–2.4	–3.0	2.4	–7.2
Refineries		–94.0	90.8	–2.1		–0.2	–5.5
Statistical differences		4.8	–2.2				2.6
Gross final consumption	0.8	–	29.2	12.1		2.2	44.3
				1973			
Primary energy production	0.4	949.8	6.5	21.9	3.0		981.6
Imports (+)	0.6	24.3	6.8	–		–	31.7
Exports (–)	–	–880.9	–38.0	–5.2		–	–924.1
International bunkers (–)	–	–	–23.7				–23.7
Changes in stocks (±)	–	–0.8	0.2	–			–0.6
Total primary energy requirements	1.0	92.4	–48.2	16.7	3.0	–	64.9
Electricity generation	–0.4	–0.4	–3.9	–2.8	–3.0	2.6	–7.9
Refineries		–95.6	92.4	–2.1		–0.2	–5.5
Statistical differences		3.6	–1.9				1.7
Gross final consumption	0.6	–	38.4	11.8		2.4	53.2
				1974			
Primary energy production	0.4	937.1	7.9	24.0	3.6		973.0
Imports (+)	0.8	24.8	8.3	–		–	33.9
Exports (–)	–	–867.3	–36.7	–5.2		–	–909.2
International bunkers (–)	–	–	–22.7				–22.7
Changes in stocks (±)	–	–3.6	0.3	–			–3.3
Total primary energy requirements	1.2	91.0	–42.9	18.8	3.6	–	71.7
Electricity generation	–0.4	–0.4	–4.2	–3.5	–3.6	3.0	–9.1
Refineries		–100.4	97.0	–2.2		–0.2	–5.8
Statistical differences		9.8	–2.1				7.7
Gross final consumption	0.8	–	47.8	13.1		2.8	64.5
				1975			
Primary energy production	0.5	861.4	8.2	29.2	3.8		903.1
Imports (+)	1.4	22.4	8.2	–		–	32.0
Exports (–)	–	–793.0	–36.1	–6.5		–	–835.6
International bunkers (–)	–	–	–14.7				–14.7
Changes in stocks (±)	–	–7.7	–0.4	–			–8.1
Total primary energy requirements	1.9	83.1	–34.8	22.7	3.8	–	76.7
Electricity generation	–0.5	–0.5	–5.0	–4.4	–3.8	3.5	–10.7
Refineries		–87.4	84.4	–1.9		–0.2	–5.1
Statistical differences		4.8	–1.9				2.9
Gross final consumption	1.4	–	42.7	16.4		3.3	63.8

Table A1.2 (continued)

Energy Balances of the Arab World, 1960-1978 (Mtoe)

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1976			
Primary energy production	0.5	995.7	10.7	30.9	4.4		1,042.2
Imports (+)	0.9	23.1	11.0	–		–	35.0
Exports (–)	–	–914.7	–42.1	–8.2		–	–965.0
International bunkers (–)	–	–	–16.1				–16.1
Changes in stocks (±)	–	–7.7	0.3	–			–7.4
Total primary energy requirements	1.4	96.4	–36.2	22.7	4.4	–	88.7
Electricity generation	–0.5	–0.7	–5.4	–5.5	–4.4	4.1	–12.4
Refineries		–94.8	91.6	–2.1		–0.2	–5.5
Statistical differences		–0.9	–3.2				–4.1
Gross final consumption	0.9	–	46.8	15.1		3.9	66.7
				1977			
Primary energy production	0.5	1,035.8	11.8	30.7	5.1		1,083.9
Imports (+)	1.1	24.3	11.2	–		–	36.6
Exports (–)	–	–959.3	–41.4	–8.1		–	–1,008.8
International bunkers (–)	–	–	–15.0				–15.0
Changes in stocks (±)	–	–12.4	0.1	–			–12.3
Total primary energy requirements	1.6	88.4	–33.3	22.6	5.1	–	84.4
Electricity generation	–0.5	–0.8	–6.3	–6.7	–5.1	4.9	–14.5
Refineries		–104.0	100.5	–2.3		–0.2	–6.0
Statistical differences		16.4	–3.7				12.7
Gross final consumption	1.1	–	57.2	13.6		4.7	76.6
				1978			
Primary energy production	0.5	987.7	13.0	37.1	5.2		1,043.5
Imports (+)	1.1	24.6	10.5	–		–	36.2
Exports (–)	–	–909.4	–48.7	–14.6		–	–972.7
International bunkers (–)	–	–	–15.6				–15.6
Changes in stocks (±)	–	–9.6	–0.1	–			–9.7
Total primary energy requirements	1.6	93.3	–40.9	22.5	5.2	–	81.7
Electricity generation	–0.5	–0.9	–7.6	–8.5	–5.2	5.8	–16.9
Refineries		–112.7	108.9	–2.5		–0.2	–6.5
Statistical differences		20.3	–4.2				16.1
Gross final consumption	1.1	–	56.2	11.5		5.6	74.4

energy balances for the years 1960 to 1970, the second for the year 1971, the third for the year 1972, and the fourth for the years 1973 to 1978. This was particularly true of the first six rows of the energy balances concerning fossil fuels (columns 1 to 4), as well as of refinery output (row 8, column 3), and NGL entering refineries (row 9, column 3).

WES data, however, had to be revised in the following cases:

1. For the year 1978, where WES preliminary figures were replaced by recently published statistics or by official information obtained through correspondence or field missions.

2. For natural gas production and use, where WES data for recent years were replaced by comparable figures obtained from OPEC sources.

3. For hydropower and conventional thermal electricity generation as well as trade in electricity, where WES data were revised and some missing statistics introduced, in light of official information obtained through correspondence, field missions, or country publications.

Regarding thermal fuel inputs, i.e., the solid fuels, crude petroleum, petroleum products, and natural gas burnt as fuel in conventional thermal power plants (row 7, columns 1 to 4), their estimation was made for each of the twenty-one Arab countries on the basis of official information obtained through correspondence and field missions or from country publications, for those years for which such information was available. The interpolation method, coupled with some good-sensical "guestimation," was used for missing years.

For the conversion of hydroelectricity into primary electricity production (row 1, column 5), i.e., into conventional thermal power plants' fuel input equivalent (row 7, column 5), the average thermal efficiency ratio of each of the twenty-one Arab countries was compiled on the basis of that country's thermal generation data and corresponding fuel inputs by type, as estimated above. Primary electricity production for each country and for each year was then derived as indicated in Table A1.1 (last entry).

At this point, the first seven rows of each Arab country's energy balance sheet for the years 1960–1978 were complete. They were aggregated into the first seven rows of an Arab world energy balance. Net electricity trade (row 6, column 6) was found to be nil because intra-Arab electricity flows cancel out in a regional perspective and there has so far been no such trade with non-Arab countries.

Concerning the "Refineries" row (row 8), Arab refinery output (row 8, column 3) was compiled by adding up country data from WES for the various types of refinery products, after conversion into toe. Refineries' own energy consumption and losses (row 8, columns 2, 4, 6, and 7) were estimated for the Arab world as a whole at 6 percent of the heat value of total refinery output, distributed between crude petroleum (3.5 percent), natural gas (2.3 percent), and electricity (0.2 percent). Such estimation was carried out on the basis of interviews, company reports, and some country data, as well as similar historical statistics published by the OECD and the CEC for their member countries. It should be noted, however, that further research would be desirable in this direction, in order to produce more accurate estimates of throughput, energy consumption, and losses of major refineries in the Arab world.

Finally, statistical differences (row 9) were calculated as follows: under crude petroleum (column 2), they are the balancing quantity to zero of the total of column 2; and under petroleum products (column 3), they represent that quantity of NGL entering refineries, as a negative figure (the same quantity being included under column 2 as a positive entry—see explanations for row 9 above).

APPENDIX TWO
THE ARAB WORLD IN INTERNATIONAL OIL MOVEMENTS, 1970 - 1977

Matrix Tables A2.1 to A2.8 below were mainly compiled on the basis of data appearing in various issues of United Nations' *World Energy Supplies* [17]. Issues nos. 18, 20, and 21 (Table 7) were used in the preparation of Tables A2.1, A2.2, and A2.3, respectively, and issue no. 22 (Table 11) was used in the preparation of Tables A2.4 to A2.8. However, the table for 1970 should not be regarded as directly comparable to the 1971–1977 tables and is not as accurate.

Some changes and revisions were introduced in the original 1970–1977 data, for better accuracy and coverage. The tables represent a reconciliation of exporter and importer data on direction of trade in crude petroleum, based on the general trade system. The total volume of trade was keyed into the exporters totals, the reconciliation being conducted among importing partners.

Exporters are shown in columns and are divided into five broad categories:

1. "Arab World" (column 14), again subdivided into "Arab Countries in OPEC" (column 12) and "Non-OPEC Arab Countries" (column 13). Columns 12 and 13 are further broken down into columns 1 to 7[1] and 8 to 11, respectively, to show individual country exports.

2. "Non-Arab OPEC Countries" (column 15), comprising Ecuador, Gabon, Indonesia, Iran, Nigeria, and Venezuela, not shown separately but with individual total exports indicated in footnote a to each table.

3. "OPEC Countries" (column 16), comprising the sum of "Arab Countries in OPEC" (column 12) and "Non-Arab OPEC Countries" (column 15).

4. "Centrally-Planned Economies" (column 17), including mainly exports from China and the USSR.

5. "Other World" (column 18), covering all other exporting countries.

Importers are shown in rows and are divided into five broad categories:[2]

1. "OECD Countries," again subdivided into major OECD countries or groupings.

2. "Arab World," also subdivided into Arab crude oil importing countries.

3. "Non-Arab Africa," comprising all countries in Africa except Arab countries in Africa.

4. "Centrally-Planned Europe," comprising Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and the USSR.

[1] In the tables for 1974 and 1977, column 12 also includes exports from Bahrain (not shown separately but indicated in footnote).

[2] Underlined figures are broad category totals. Figures between parentheses indicate further breakdown of groupings within a broad category.

5. "Other Countries," covering all other importing countries. Of these, major clients of the Arab world are shown separately, some of which are followed by the letter (D) to indicate a special status relationship with an OECD member country (territory, colony, etc.).

Table A2.9 below was compiled on the basis of data appearing in OECD's *Oil Statistics: Supply and Disposal* [18] for the year 1977 (Table A).

Matrix Tables A2.10 to A2.14 below were also compiled on the basis of data appearing in OECD's *Oil Statistics: Supply and Disposal* for the years 1973 to 1977 (Tables 31 to 46 of the issues for 1973 to 1976 and Tables 94 to 109 of the issue for 1977). Some changes and revisions were introduced in the original data, based on additional information.

Exporters are shown in columns and follow a similar breakdown to that of Tables A2.1 to A2.8. Importers are shown in rows and are limited to "OECD Countries" only. This category follows the same subdivision into major OECD countries or groupings as in Tables A2.1 to A2.8.

While Tables A2.1 to A2.9 relate to crude oil, Tables A2.10 to A2.14 are concerned with petroleum products as defined in Appendix 1, i.e., refinery petroleum products and natural gas liquids.

Quantities appearing in the tables are expressed in thousand toe (Tables A2.1 to A2.8) or Mtoe (A2.9 to A2.14), obtained from the original data on the basis of the relevant conversion factors as indicated in Table A1.1.

Table A2.1

The Arab World in International Crude Oil Movements, 1970 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	42,405.1	61,616.5	112,769.6	157,550.2	13,294.7	127,513.1	31,785.8	8,736.3	17,050.6	1,903.7
USA	277.8	–	2,662.0	2,325.5	–	2,288.5	3,189.9	1,131.9	–	–
Canada	–	1,193.6	639.6	–	–	1,562.4	720.3	–	–	–
Japan	–	–	31,058.9	329.3	174.9	28,540.8	8,870.0	1,389.2	4,239.5	–
OECD Europe	42,127.3	59,085.2	72,953.6	154,895.4	11,751.2	90,801.4	18,419.1	6,215.2	12,811.1	1,903.7
(EEC)	(40,285.4)	(48,239.5)	(69,210.0)	(141,353.7)	(10,794.2)	(78,389.7)	(15,898.1)	(4,877.5)	(9,240.4)	(154.4)
(Other OECD Europe)	(1,841.9)	(10,845.7)	(3,743.6)	(13,541.7)	(957.0)	(12,411.7)	(2,521.0)	(1,337.7)	(3,570.7)	(1,749.3)
OECD Oceania	–	1,337.7	5,455.5	–	1,368.6	4,320.0	586.5	–	–	–
Arab World	937.4	3,729.8	2,551.4	–	102.9	10,716.9	957.0	41.2	–	696.0
Bahrain	–	–	–	–	–	8,941.0	–	–	–	–
Democratic Yemen	–	421.9	2,031.7	–	102.9	211.5	957.0	41.2	–	–
Egypt	–	–	–	–	–	–	–	–	–	696.0
Jordan	–	–	–	–	–	493.9	–	–	–	–
Lebanon	–	1,668.7	–	–	–	381.1	–	–	–	–
Morocco	844.8	–	–	–	–	–	–	–	–	–
Saudi Arabia	–	–	519.7	–	–	–	–	–	–	–
Sudan	–	–	–	–	–	689.4	–	–	–	–
Syrian Arab Republic	–	1,287.3	–	–	–	–	–	–	–	–
Tunisia	92.6	351.9	–	–	–	–	–	–	–	–
Non-Arab Africa	792.3	3,169.3	329.3	–	2,438.7	5,237.7	257.3	51.5	–	–
Centrally Planned Europe	710.0	2,479.9	–	61.7	–	–	–	3,725.0	–	483.6
Other Countries[c]	1,666.0	4,442.5	17,503.3	6,256.4	2,064.2	20,695.9	5,704.7	720.1	14.4	539.8
Bahamas (D)	–	–	–	751.2	–	–	–	–	–	–
Brazil	1,512.6	3,344.3	1,552.0	545.4	72.0	3,479.8	–	720.1	–	–
Guam (D)	–	–	–	–	–	–	–	–	–	–
India	–	–	–	–	–	3,704.4	–	–	–	–
Korea	–	–	2,351.5	–	–	3,410.9	–	–	–	–
Martinique (D)	–	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	–	–	195.5	–	–	–	–	–	–
Philippines	–	30.9	2,428.8	–	–	1,020.3	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	236.7	–	–	–	–
Singapore	–	61.7	7,355.6	–	–	1,771.7	–	–	–	–
Thailand	–	164.6	–	–	1,595.0	1,872.8	–	–	–	–
Trinidad	–	–	–	2,099.2	–	2,963.5	–	–	–	–
US Virgin Islands (D)	–	–	–	2,665.1	–	–	–	–	–	–
World	46,510.8	75,438.0	133,153.6	164,068.9	17,900.5	164,163.6	38,704.8	13,274.1	17,065.0	3,623.1

[a] The total export figure of 390,114.5 is subdivided into: Ecuador 41.2; Gabon 4,640.8; Indonesia 30,715.6; Iran 170,227.5; Nigeria 53,199.3; and Venezuela 131,290.1.

[b] Of which US imports from Canada 33,493.9.

[c] Also includes exports to unspecified destinations.

Note:

A dash (–) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	3,035.6	546,935.0	30,726.2	577,661.2	260,069.4	807,004.4	25,570.7	46,037.3	909,338.6
USA	–	10,743.7	1,131.9	11,875.6	22,020.6	32,764.3	–	35,139.4[b]	69,035.6
Canada	–	4,115.9	–	4,115.9	24,737.2	28,853.1	–	1,245.2	30,098.3
Japan	–	68,973.9	5,628.7	74,602.6	99,257.3	168,231.2	514.5	1,162.7	175,537.1
OECD Europe	3,035.6	450,033.2	23,965.6	473,998.8	110,689.5	560,722.7	25,056.2	7,408.5	617,153.0
(EEC)	(2,798.9)	(404,170.6)	(17,071.2)	(421,241.8)	(92,332.2)	(496,502.8)	(15,424.7)	(5,103.7)	(534,102.4)
(Other OECD Europe)	(236.7)	(45,862.6)	(6,894.4)	(52,757.0)	(18,357.3)	(64,219.9)	(9,631.4)	(2,304.8)	(83,050.6)
OECD Oceania	–	13,068.3	–	13,068.3	3,364.8	16,433.1	–	1,080.5	17,513.6
Arab World	–	18,995.4	737.2	19,732.6	3,330.8	22,326.2	1,605.3	–	24,668.7
Bahrain	–	8,941.0	–	8,941.0	–	8,941.0	–	–	8,941.0
Democratic Yemen	–	3,725.0	41.2	3,766.2	3,238.2	6,963.2	–	–	7,004.4
Egypt	–	–	696.0	696.0	–	–	967.3	–	1,663.3
Jordan	–	493.9	–	493.9	–	493.9	–	–	493.9
Lebanon	–	2,049.8	–	2,049.8	–	2,049.8	–	–	2,049.8
Morocco	–	844.8	–	844.8	92.6	937.4	638.0	–	1,575.4
Saudi Arabia	–	519.7	–	519.7	–	519.7	–	–	519.7
Sudan	–	689.4	–	689.4	–	689.4	–	–	689.4
Syrian Arab Republic	–	1,287.3	–	1,287.3	–	1,287.3	–	–	1,287.3
Tunisia	–	444.5	–	444.5	–	444.5	–	–	444.5
Non-Arab Africa	226.3	12,224.6	277.8	12,502.4	5,608.0	17,832.6	524.8	30.9	18,666.1
Centrally Planned Europe	–	3,251.6	4,208.6	7,460.2	2,284.4	5,536.0	36,889.7	–	46,634.3
Other Countries	–	58,533.6	1,274.3	59,807.9	118,821.9	177,355.5	4,692.1	15,682.1	199,004.0
Bahamas (D)	–	751.2	–	751.2	1,265.7	2,016.9	–	555.6	2,572.5
Brazil	–	10,506.1	720.1	11,226.2	6,235.7	16,741.8	–	278.1	17,740.0
Guam (D)	–	–	–	–	–	–	–	–	–
India	–	3,704.4	–	3,704.4	8,334.9	12,039.3	–	–	12,039.3
Korea	–	5,762.4	–	5,762.4	3,272.2	9,034.6	–	102.9	9,137.5
Martinique (D)	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	195.5	–	195.5	46,881.2	47,076.7	–	236.7	47,313.4
Philippines	–	3,480.0	–	3,480.0	4,589.3	8,069.3	–	1,253.4	9,322.7
Puerto Rico (D)	–	236.7	–	236.7	6,585.6	6,822.3	–	493.9	7,316.2
Singapore	–	9,189.0	–	9,189.0	1,203.9	10,392.9	–	411.6	10,804.5
Thailand	–	3,632.4	–	3,632.4	102.9	3,735.3	–	319.0	4,054.3
Trinidad	–	5,062.7	–	5,062.7	10,073.9	15,136.6	–	1,008.4	16,145.0
US Virgin Islands (D)	–	2,665.1	–	2,665.1	10,413.6	13,078.7	–	1,368.5	14,447.2
World	3,261.9	639,940.2	37,224.1	677,164.3	390,114.5	1,030,054.7	69,282.6	61,750.3	1,198,311.7

Table A2.2

The Arab World in International Crude Oil Movements, 1971 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	31,127.3	66,432.3	115,834.5	120,917.7	15,867.2	168,858.8	47,447.2	6,503.3	14,951.4	3,375.1
USA	627.7	545.4	2,881.2	2,634.2	–	5,145.0	4,116.0	987.8	–	–
Canada	–	1,255.4	–	277.8	72.0	2,140.3	411.6	–	–	–
Japan	–	144.1	26,218.9	421.9	72.0	39,050.5	13,685.7	668.9	1,543.5	–
OECD Europe	30,499.6	62,408.8	81,939.3	117,583.8	15,064.6	120,547.3	27,690.4	(4,764.3)	13,407.9	3,375.1
(EEC)	(27,175.9)	(50,359.3)	(76,629.6)	(108,034.7)	(13,037.4)	(104,762.5)	(22,980.2)	(3,539.8)	(10,794.2)	(1,769.9)
(Other OECD Europe)	(3,323.7)	(12,049.5)	(5,309.7)	(9,549.1)	(2,027.2)	(15,784.8)	(4,710.2)	(1,224.5)	(2,613.7)	(1,605.2)
OECD Oceania	–	2,078.6	4,795.1	–	658.6	1,975.7	1,543.5	82.3	–	–
Arab World	836.7	3,449.3	1,830.6	488.8	216.1	11,353.0	133.8	41.2	–	30.8
Bahrain	–	–	–	–	–	9,283.7	–	–	–	–
Democratic Yemen	–	936.4	1,224.5	–	216.1	–	133.8	10.3	–	–
Egypt	30.9	175.0	–	488.8	–	–	–	–	–	30.8
Jordan	–	–	–	–	–	609.2	–	–	–	–
Lebanon	–	1,328.5	–	–	–	791.2	–	–	–	–
Morocco	713.2	–	–	–	–	–	–	30.9	–	–
Saudi Arabia	–	–	606.1	–	–	–	–	–	–	–
Sudan	–	–	–	–	–	668.9	–	–	–	–
Syrian Arab Republic	–	771.7	–	–	–	–	–	–	–	–
Tunisia	92.6	237.7	–	–	–	–	–	–	–	–
Non-Arab Africa	205.8	3,323.7	113.2	–	2,747.4	4,630.5	1,759.6	30.9	–	–
Centrally Planned Europe	1,029.0	1,080.4	–	545.4	–	–	–	2,942.9	–	159.6
Other Countries	2,037.3	7,593.9	25,897.9	12,646.5	2,310.1	29,638.3	3,057.1	1,286.2	4.1	–
Bahamas (D)	–	–	–	4,733.4	–	133.8	–	–	–	–
Brazil	1,934.5	3,087.0	1,605.9	689.4	504.2	6,431.3	–	926.1	–	–
Guam (D)	–	–	–	–	72.1	1,214.2	–	–	–	–
India	–	20.6	–	–	–	2,819.5	–	–	–	–
Korea	–	–	6,163.7	–	–	3,930.8	–	–	–	–
Martinique (D)	61.7	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	–	–	339.6	–	–	823.2	–	–	–
Philippines	–	82.3	2,181.5	–	–	1,337.7	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	349.9	761.5	–	–	–
Singapore	–	30.9	8,674.5	–	–	2,932.6	–	–	–	–
Thailand	–	102.9	432.2	–	1,733.8	2,263.8	–	–	–	–
Trinidad	–	–	–	3,395.7	–	4,414.4	–	–	–	–
US Virgin Islands (D)	–	–	–	3,272.2	–	–	–	–	–	–
World	35,236.1	81,879.6	143,676.2	134,598.4	21,140.8	214,480.6	52,397.7	10,804.5	14,955.5	3,565.5

[a]The total export figure of 441,832.0 is subdivided into: Ecuador 51.4; Gabon 4,980.4; Indonesia 33,360.2; Iran 204,575.5; Nigeria 74,561.3; and Venezuela 124,303.2.

[b]Of which US imports from Canada 35,860.6.

Note:

A dash (–) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	2,829.7	566,485.0	27,659.5	594,144.5	306,189.3	872,674.3	27,628.7	48,568.8	976,531.3
USA	164.6	15,949.5	1,152.5	17,102.0	31,734.4	47,683.9	—	37,496.7[b]	86,333.1
Canada	–	4,157.1	–	4,157.1	28,832.6	32,989.7	—	2,284.4	35,274.1
Japan	–	79,593.1	2,212.3	81,805.4	109,434.1	189,027.2	1,543.5	3,766.3	196,549.3
OECD Europe	2,665.1	455,733.8	24,212.4	479,946.2	134,397.7	590,131.5	26,085.2	4,455.5	644,884.6
(EEC)	(1,934.5)	(402,979.6)	(18,038.4)	(421,018.0)	(114,990.7)	(517,970.3)	(16,916.9)	(3,382.7)	(556,308.3)
(Other OECD Europe)	(730.6)	(52,754.2)	(6,174.0)	(58,928.2)	(19,407.0)	(72,161.2)	(9,168.3)	(1,072.8)	(88,576.3)
OECD Oceania	–	11,051.5	82.3	11,133.8	1,790.5	12,842.0	–	565.9	13,490.2
Arab World	–	18,308.3	72.0	18,380.3	1,417.9	19,726.2	1,718.4	–	21,516.6
Bahrain	–	9,283.7	–	9,283.7	–	9,283.7	–	–	9,283.7
Democratic Yemen	–	2,510.8	10.3	2,521.1	1,335.6	3,846.4	–	–	3,856.7
Egypt	–	694.7	30.8	725.5	–	694.7	843.8	–	1,569.3
Jordan	–	609.2	–	609.2	–	609.2	–	–	609.2
Lebanon	–	2,119.7	–	2,119.7	–	2,119.7	–	–	2,119.7
Morocco	–	713.2	30.9	744.1	82.3	795.5	874.6	–	1,701.0
Saudi Arabia	–	606.1	–	606.1	–	606.1	–	–	606.1
Sudan	–	668.9	–	668.9	–	668.9	–	–	668.9
Syrian Arab Republic	–	771.7	–	771.7	–	771.7	–	–	771.7
Tunisia	–	330.3	–	330.3	–	330.3	–	–	330.3
Non-Arab Africa	185.2	12,780.3	216.1	12,996.4	9,580.0	22,360.3	617.4	10.1	23,203.9
Centrally Planned Europe	10.3	2,654.8	3,112.8	5,767.6	3,642.7	6,297.5	40,830.7	–	50,241.0
Other Countries	3.3	83,181.0	1,293.6	84,474.6	121,002.1	204,183.1	6,544.4	17,883.0	229,904.1
Bahamas (D)	–	4,867.2	–	4,867.2	4,733.4	9,600.6	–	432.0	10,032.8
Brazil	–	14,251.6	926.1	15,177.7	3,694.1	17,945.7	–	545.4	19,417.2
Guam (D)	–	1,286.3	–	1,286.3	–	1,286.3	–	–	1,286.3
India	–	2,840.1	–	2,840.1	10,248.8	13,088.9	–	–	13,088.9
Korea	–	10,094.5	–	10,094.5	3,550.0	13,644.5	–	92.7	13,737.2
Martinique (D)	–	61.7	–	61.7	339.6	401.3	–	–	401.3
Netherlands Antilles (D)	–	1,162.8	–	1,162.8	39,174.0	40,336.8	–	493.9	40,830.7
Philippines	–	3,601.5	–	3,601.5	4,023.4	7,624.9	–	1,564.1	9,189.0
Puerto Rico (D)	–	1,111.4	–	1,111.4	11,761.5	12,872.9	–	730.5	13,603.4
Singapore	–	11,638.0	–	11,638.0	2,469.6	14,107.6	–	1,749.3	15,856.9
Thailand	–	4,532.7	–	4,532.7	174.9	4,707.6	–	849.0	5,556.6
Trinidad	–	7,810.1	–	7,810.1	6,781.1	14,591.2	–	473.4	15,064.6
US Virgin Islands (D)	–	3,272.2	–	3,272.2	13,562.2	16,834.4	–	1,502.4	18,336.8
World	3,028.5	683,409.4	32,354.0	715,763.4	441,832.0	1,125,241.4	77,339.6	66,461.9	1,301,396.9

Table A2.3

The Arab World in International Crude Oil Movements, 1972 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	42,744.8	49,855.1	117,964.6	96,890.6	16,978.5	226,493.2	54,269.6	3,591.2	14,179.6	3,498.6
USA	4,476.2	308.7	1,862.5	5,649.2	174.9	8,972.9	3,786.7	432.2	–	–
Canada	51.5	1,996.3	154.4	1,913.9	421.9	3,961.6	1,893.4	–	–	–
Japan	–	102.9	27,237.6	195.5	174.9	47,838.2	12,914.0	195.5	7,367.6	–
OECD Europe	38,217.1	45,759.6	84,203.1	89,132.0	15,682.0	163,734.5	34,008.5	2,963.5	6,812.0	3,498.6
(EEC)	(31,394.8)	(36,406.0)	(78,389.2)	(82,680.2)	(14,632.4)	(139,378.0)	(29,069.3)	(2,078.6)	(3,951.4)	(2,099.2)
(Other OECD Europe)	(6,822.3)	(9,353.6)	(5,813.9)	(6,451.8)	(1,049.6)	(24,356.5)	(4,939.2)	(884.9)	(2,860.6)	(1,399.4)
OECD Oceania	–	1,687.6	4,507.0	–	524.8	1,986.0	1,667.0	–	–	–
Arab World	968.4	3,374.4	2,213.4	–	421.9	10,924.9	391.0	82.3	–	–
Bahrain	–	–	–	–	–	8,507.8	–	–	–	–
Democratic Yemen	–	324.2	1,564.1	–	391.0	–	391.0	–	–	–
Egypt	154.4	344.8	–	–	–	–	–	–	–	–
Jordan	–	–	–	–	–	661.7	–	–	–	–
Lebanon	–	1,433.4	–	–	–	771.8	–	–	–	–
Morocco	793.4	–	–	–	–	–	–	82.3	–	–
Saudi Arabia	–	–	649.3	–	–	–	–	–	–	–
Sudan	–	621.6	–	–	–	500.0	–	–	–	–
Syrian Arab Republic	–	628.7	–	–	–	–	–	–	–	–
Tunisia	20.6	21.7	–	–	30.9	483.6	–	–	–	–
Non-Arab Africa	51.5	3,313.3	–	–	1,985.9	4,692.3	308.7	–	–	–
Centrally Planned Europe	1,214.2	6,153.4	–	2,726.9	–	–	–	1,996.3	–	820.1
Other Countries	2,589.7	7,666.8	31,843.4	10,555.5	4,483.4	36,709.5	4,772.4	941.5	860.3	–
Bahamas (D)	–	–	–	2,819.5	–	–	–	–	–	–
Brazil	1,780.2	4,949.5	1,852.2	812.9	247.0	10,434.1	–	–	339.6	–
Guam (D)	–	–	1,317.2	–	277.8	–	–	–	–	–
India	–	–	–	–	–	2,675.4	–	–	–	–
Korea	–	–	7,594.0	–	–	4,260.1	–	–	–	–
Martinique (D)	185.2	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	–	885.0	–	1,852.2	–	1,471.5	–	–	–
Philippines	–	277.8	1,142.2	–	411.6	3,848.5	–	–	–	–
Puerto Rico (D)	339.6	–	154.4	–	–	1,131.9	1,697.9	–	–	–
Singapore	–	617.4	9,508.0	–	–	3,334.0	–	–	–	–
Thailand	–	61.7	1,420.0	–	1,694.8	2,675.4	–	–	–	–
Trinidad	–	–	–	3,157.0	–	3,858.8	–	–	–	–
US Virgin Islands (D)	113.2	–	–	3,766.1	–	144.1	–	–	–	–
World	47,568.6	70,363.0	152,021.4	110,173.0	23,869.7	278,819.9	59,741.7	6,611.3	15,039.9	4,318.7

[a]The total export figure of 488,548.6 is subdivided into: Ecuador 3,508.9; Gabon 5,505.1; Indonesia 41,890.6; Iran 232,183.6; Nigeria 90,747.5; and Venezuela 114,712.9.

[b]Of which US imports from Canada 43,856.0.

Note:

A dash (–) indicates nil or negligible.

Importers / Exporters	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	3,683.8	605,196.4	24,953.2	630,149.6	347,400.7	952,597.1	23,430.3	66,597.2	1,067,577.8
USA	360.2	17,131.1	792.4	17,923.5	41,777.4	58,908.5	41.2	54,404.9[b]	114,147.0
Canada	–	10,393.0	–	10,393.0	28,328.4	38,721.4	–	2,963.4	41,684.8
Japan	–	88,463.1	7,563.1	96,026.2	116,863.5	205,326.6	370.4	6,853.2	220,113.9
OECD Europe	3,323.6	470,736.8	16,597.7	487,334.5	159,248.0	629,984.8	23,018.7	9,981.3	679,582.5
(EEC)	(3,117.9)	(411,949.9)	(11,247.1)	(423,197.0)	(138,544.6)	(550,494.5)	(13,459.3)	(6,225.3)	(581,426.2)
(Other OECD Europe)	(201.7)	(58,786.9)	(5,350.6)	(64,137.5)	(20,703.4)	(79,490.3)	(9,559.4)	(3,756.2)	(98,156.3)
OECD Oceania	–	10,372.4	–	10,372.4	1,183.4	11,555.8	–	493.8	12,049.6
Arab World	–	18,294.0	82.3	18,376.3	1,101.0	19,395.0	1,769.8	–	21,247.1
Bahrain	–	8,507.8	–	8,507.8	–	8,507.8	–	–	8,507.8
Democratic Yemen	–	2,670.3	–	2,670.3	812.9	3,483.2	–	–	3,483.2
Egypt	–	499.2	–	499.2	–	499.2	915.8	–	1,415.0
Jordan	–	661.7	–	661.7	–	661.7	–	–	661.7
Lebanon	–	2,205.2	–	2,205.2	–	2,205.2	–	–	2,205.2
Morocco	–	793.4	82.3	875.7	82.3	875.7	854.1	–	1,812.1
Saudi Arabia	–	649.3	–	649.3	–	649.3	–	–	649.3
Sudan	–	1,121.6	–	1,121.6	–	1,121.6	–	–	1,121.6
Syrian Arab Republic	–	628.7	–	628.7	–	628.7	–	–	628.7
Tunisia	–	556.8	–	556.8	205.8	762.6	–	–	762.6
Non-Arab Africa	122.5	10,351.7	122.5	10,474.2	11,833.5	22,185.2	627.7	20.6	22,956.0
Centrally Planned Europe	–	10,094.5	2,816.4	12,910.9	7,203.0	17,297.5	48,229.2	–	68,343.1
Other Countries	–	98,620.7	1,801.8	100,422.5	121,010.4	219,631.1	5,412.6	10,817.6	237,663.1
Bahamas (D)	–	2,819.5	–	2,819.5	7,028.1	9,847.6	–	586.5	10,434.1
Brazil	–	20,075.9	339.6	20,415.5	3,015.0	23,090.9	–	174.8	23,605.3
Guam (D)	–	1,595.0	–	1,595.0	–	1,595.0	–	–	1,595.0
India	–	2,675.4	–	2,675.4	9,960.7	12,636.1	–	–	12,636.1
Korea	–	11,854.1	–	11,854.1	277.8	12,131.9	–	730.6	12,862.5
Martinique (D)	–	185.2	–	185.2	164.7	349.9	–	–	349.9
Netherlands Antilles (D)	–	4,208.7	–	4,208.7	36,838.2	41,046.9	–	411.5	41,458.4
Philippines	–	5,680.1	–	5,680.1	1,883.1	7,563.2	–	1,543.4	9,106.7
Puerto Rico (D)	–	3,323.8	–	3,323.7	12,481.8	15,805.6	–	514.4	16,319.9
Singapore	–	13,459.4	–	13,459.3	4,218.9	17,678.2	–	2,696.0	20,374.2
Thailand	–	5,851.9	–	5,851.9	72.0	5,923.9	–	826.3	6,750.2
Trinidad	–	7,015.8	–	7,038.4	6,851.1	13,912.1	–	1,072.2	14,961.7
US Virgin Islands (D)	–	4,023.4	–	4,023.4	14,179.6	18,203.0	92.6	1,018.7	19,314.3
World	3,806.3	742,557.3	29,776.2	772,333.5	488,548.6	1,231,105.9	79,469.7	77,435.3	1,417,787.1

Table A2.4

The Arab World in International Crude Oil Movements, 1973 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	44,329.3	65,392.9	106,141.4	93,742.0	20,117.1	279,713.0	67,872.8	2,891.5	14,334.0	4,352.7
USA	6,379.8	277.8	2,109.5	6,606.2	360.2	15,548.2	3,797.0	761.5	298.4	–
Canada	61.7	1,121.6	607.1	1,769.9	–	3,395.7	2,942.9	–	1,378.9	–
Japan	–	1,440.6	23,687.6	874.7	113.2	60,165.6	24,058.0	72.0	5,350.8	–
OECD Europe	37,887.8	60,824.2	74,427.6	84,491.2	19,088.0	198,360.3	36,848.5	2,058.0	6,647.3	4,352.7
(EEC)	(31,343.3)	(48,085.2)	(68,654.9)	(77,082.4)	(17,678.2)	(167,655.0)	(30,890.6)	(1,605.2)	(4,928.9)	(2,377.0)
(Other OECD Europe)	(6,544.5)	(12,739.0)	(5,772.7)	(7,408.8)	(1,409.8)	(30,705.3)	(5,957.9)	(452.8)	(1,718.4)	(1,975.7)
OECD Oceania	–	1,728.7	5,309.6	–	555.7	2,243.2	226.4	–	658.6	–
Arab World	1,198.9	5,191.4	1,772.1	566.8	–	13,182.8	244.3	205.8	–	–
Bahrain	–	–	–	–	–	9,067.5	–	–	–	–
Democratic Yemen	–	816.4	1,382.1	–	–	–	244.3	–	–	–
Egypt	212.2	907.0	–	566.8	–	927.6	–	–	–	–
Jordan	–	–	–	–	–	726.5	–	–	–	–
Lebanon	–	1,780.2	–	–	–	843.8	–	–	–	–
Morocco	966.1	–	10.3	–	–	–	–	205.8	–	–
Saudi Arabia	–	–	379.7	–	–	–	–	–	–	–
Sudan	–	198.8	–	–	–	1,000.0	–	–	–	–
Syrian Arab Republic	–	1,067.1	–	–	–	–	–	–	–	–
Tunisia	20.6	421.9	–	–	–	617.4	–	–	–	–
Non-Arab Africa	51.5	4,455.6	154.4	30.9	2,232.9	5,536.0	185.2	–	–	–
Centrally Planned Europe	1,101.0	11,442.5	442.5	3,889.6	–	30.9	–	1,286.3	102.9	–
Other Countries	590.5	11,263.3	28,722.2	9,672.7	5,932.1	59,985.3	7,839.6	246.9	603.0	97.7
Bahamas (D)	–	–	–	4,311.5	–	360.2	–	–	–	–
Brazil	–	7,851.3	2,654.8	1,656.7	308.7	15,393.8	–	247.0	164.6	–
Guam (D)	–	–	391.0	–	308.7	895.2	–	–	–	–
India	–	–	–	–	–	3,498.6	–	–	–	–
Korea	–	1,306.8	4,332.1	–	–	8,252.6	–	–	–	–
Martinique (D)	144.1	51.5	–	–	–	10.3	–	–	–	–
Netherlands Antilles (D)	–	–	3,447.2	–	3,375.1	–	2,140.3	–	545.4	–
Philippines	–	30.9	1,276.0	–	195.5	5,206.7	216.1	–	–	–
Puerto Rico (D)	–	–	–	–	–	1,625.8	1,955.1	–	–	–
Singapore	–	689.4	6,740.0	–	–	5,968.2	1,862.5	–	–	–
Thailand	–	349.9	2,294.7	–	1,744.1	2,150.6	–	–	–	–
Trinidad	–	–	–	329.3	–	6,997.2	–	–	–	–
US Virgin Islands (D)	216.1	102.9	–	3,220.7	–	2,181.5	–	–	–	–
World	47,271.2	97,745.7	137,232.6	107,902.0	28,282.1	358,448.0	76,141.9	4,630.5	15,039.9	4,450.4

[a]The total export figure of 555,814.4 is subdivided into: Ecuador 10,187.1; Gabon 6,688.5; Indonesia 51,501.5; Iran 271,378.2; Nigeria 101,932.7; and Venezuela 114,126.4.

[b]Of which US imports from Canada 51,902.8.

Note:

A dash (–) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	3,735.3	677,308.5	25,313.5	702,622.0	403,244.5	1,080,553.0	26,764.3	80,179.6	1,212,810.4
USA	1,255.4	35,078.7	2,315.3	37,394.0	70,589.4	105,668.1	–	57,171.1[b]	165,154.5
Canada	–	9,898.9	1,378.9	11,277.8	32,269.4	42,168.3	–	2,963.6	46,510.8
Japan	–	110,339.7	5,422.8	115,762.5	128,799.9	239,139.6	2,243.2	10,495.9	257,301.5
OECD Europe	2,479.9	511,927.6	15,537.9	527,465.5	171,102.1	682,340.3	24,521.1	8,767.0	731,855.7
(EEC)	(1,934.5)	(441,389.6)	(10,845.6)	(452,235.2)	(147,805.6)	(585,223.3)	(14,334.0)	(6,904.5)	(621,279.3)
(Other OECD Europe)	(545.4)	(70,538.0)	(4,692.3)	(75,230.3)	(23,296.5)	(97,117.0)	(10,187.1)	(1,862.5)	(110,576.4)
OECD Oceania	–	10,063.6	658.6	10,722.2	1,173.1	11,236.7	–	92.6	11,987.9
Arab World	–	22,156.3	205.8	22,362.1	926.2	23,082.5	1,327.5	–	24,615.8
Bahrain	–	9,067.5	–	9,067.5	–	9,067.5	–	–	9,067.5
Democratic Yemen	–	2,442.8	–	2,442.8	771.8	3,214.6	–	–	3,214.6
Egypt	–	2,613.6	–	2,613.6	–	2,613.6	360.2	–	2,973.8
Jordan	–	726.5	–	726.5	–	726.5	–	–	726.5
Lebanon	–	2,624.0	–	2,624.0	–	2,624.0	–	–	2,624.0
Morocco	–	976.4	205.8	1,182.2	154.4	1,130.8	967.3	–	2,303.9
Saudi Arabia	–	379.7	–	379.7	–	379.7	–	–	379.7
Sudan	–	1,198.8	–	1,198.8	–	1,198.8	–	–	1,198.8
Syrian Arab Republic	–	1,067.1	–	1,067.1	–	1,067.1	–	–	1,067.1
Tunisia	–	1,059.9	–	1,059.9	–	1,059.9	–	–	1,059.9
Non-Arab Africa	–	12,646.5	–	12,646.5	12,296.5	24,943.0	329.3	812.9	26,085.2
Centrally Planned Europe	41.2	15,906.5	1,430.4	17,336.9	10,783.9	26,690.4	55,195.9	1,833.1	85,149.8
Other Countries	4.0	125,005.7	951.6	125,957.3	128,563.3	253,569.0	5,731.4	10,228.6	270,480.6
Bahamas (D)	–	4,671.7	–	4,671.7	8,808.2	13,479.9	–	308.7	13,788.6
Brazil	–	27,865.3	411.6	28,276.9	2,469.6	30,334.9	–	2,294.7	33,041.2
Guam (D)	–	1,594.8	–	1,594.8	–	1,594.8	–	0.2	1,595.0
India	–	3,498.6	–	3,498.6	9,899.0	13,397.6	288.1	–	13,685.7
Korea	–	13,891.5	–	13,891.5	555.7	14,447.2	–	30.8	14,478.0
Martinique (D)	–	205.9	–	205.9	–	205.9	–	298.3	504.2
Netherlands Antilles (D)	–	8,962.6	545.4	9,508.0	35,994.4	44,957.0	–	185.2	45,687.6
Philippines	–	6,925.2	–	6,925.2	2,181.5	9,106.7	–	421.8	9,528.5
Puerto Rico (D)	–	3,580.9	–	3,580.9	13,274.1	16,855.0	–	1,255.4	18,110.4
Singapore	–	7,830.7	–	7,830.7	4,537.9	12,368.6	–	9,770.4	22,139.0
Thailand	–	6,540.4	–	6,540.4	41.2	6,585.7	–	1,147.3	7,727.8
Trinidad	–	7,326.5	–	7,326.5	6,585.6	13,912.1	–	1,162.8	15,074.9
US Virgin Islands (D)	–	5,721.2	–	5,721.2	17,781.1	23,502.3	298.4	1,646.5	25,148.8
World	3,780.5	853,023.5	27,901.3	880,924.8	555,814.4	1,408,837.9	90,068.4	92,334.2	1,619,141.8

Table A2.5

The Arab World in International Crude Oil Movements, 1974 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	36,539.9	63,890.6	89,800.9	65,784.0	17,246.1	303,822.5	75,960.8	1,523.0	14,117.9	6,318.1
USA	8,674.5	308.7	915.8	205.8	946.7	22,277.9	4,064.6	463.1	30.9	–
Canada	133.8	2,572.5	1,276.0	442.5	–	4,393.8	1,214.2	–	2,284.4	–
Japan	216.1	2,479.9	26,054.3	3,210.5	226.4	59,455.6	25,519.2	102.9	6,246.0	–
OECD Europe	27,515.5	55,885.0	56,934.6	61,925.2	15,270.4	214,618.5	44,998.2	957.0	5,556.6	6,318.1
(EEC)	(23,543.5)	(41,386.4)	(52,077.7)	(56,821.4)	(14,519.2)	(177,368.7)	(37,558.5)	(957.0)	(3,529.5)	(3,375.1)
(Other OECD Europe)	(3,972.0)	(14,498.6)	(4,856.9)	(5,103.8)	(751.2)	(37,249.8)	(7,439.7)	–	(2,027.1)	(2,943.0)
OECD Oceania	–	2,644.5	4,620.2	–	802.6	3,076.7	92.6	–	–	–
Arab World	1,581.8	5,256.2	1,486.9	83.6	452.8	13,163.5	298.4	205.8	–	20.6
Bahrain	–	–	–	–	–	9,540.9	–	–	–	–
Democratic Yemen	–	–	926.1	–	247.0	–	298.4	–	–	–
Egypt	933.5	–	–	83.6	–	907.1	–	–	–	20.6
Jordan	–	–	–	–	–	795.4	–	–	–	–
Lebanon	–	1,656.7	–	–	–	812.9	–	–	–	–
Morocco	648.3	812.9	20.6	–	205.8	154.4	–	205.8	–	–
Saudi Arabia	–	–	540.2	–	–	–	–	–	–	–
Sudan	–	595.9	–	–	–	500.0	–	–	–	–
Syrian Arab Republic	–	1,776.1	–	–	–	–	–	–	–	–
Tunisia	–	414.6	–	–	–	452.8	–	–	–	–
Non-Arab Africa	144.1	3,025.3	195.5	524.8	1,358.3	2,850.3	164.6	–	–	–
Centrally Planned Europe	854.1	8,458.4	568.6	658.6	–	154.4	144.1	411.6	–	–
Other Countries	3,955.1	12,886.0	22,670.3	6,900.1	6,293.2	85,861.3	6,427.1	247.0	767.6	–
Bahamas (D)	–	–	–	1,955.1	–	4,270.4	–	–	–	–
Brazil	–	7,717.5	1,018.7	3,097.3	–	17,009.4	257.3	247.0	767.6	–
Guam (D)	–	–	473.3	–	514.5	–	–	–	–	–
India	–	3,117.9	–	–	–	4,393.8	–	–	–	–
Korea	–	483.6	4,239.5	–	–	10,073.9	–	–	–	–
Martinique (D)	51.5	51.5	–	–	–	185.2	–	–	–	–
Netherlands Antilles (D)	–	–	–	–	2,932.7	4,116.0	–	–	–	–
Philippines	–	596.8	2,109.5	–	421.9	5,217.9	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	5,145.0	2,058.0	–	–	–
Singapore	–	–	7,377.9	–	102.9	6,575.3	2,747.4	–	–	–
Thailand	–	–	1,461.2	–	2,239.0	2,973.8	–	–	–	–
Trinidad	–	–	–	–	–	7,285.3	51.5	–	–	–
US Virgin Islands (D)	3,087.0	308.7	–	1,780.2	82.3	6,832.6	411.6	–	–	–
World	43,075.0	93,516.5	114,722.2	73,951.1	25,350.4	405,852.0	82,995.0	2,387.3	14,885.5	6,338.7

[a] This column also includes an additional figure of 412.6 thousand toe's representing crude exports from Bahrain to Saudi Arabia in 1974.

[b] The total export figure 553,972.4 is subdivided into: Ecuador 8,489.3; Gabon 9,333.0; Indonesia 52,736.3; Iran 276,368.8; Nigeria 111,914.0; and Venezuela 95,131.1.

[c] Of which US imports from Canada 41, 273.2.

Note:

A dash (–) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries[a] In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[b]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	3,498.6	653,044.8	25,457.6	678,502.4	418,761.9	1,057,174.4	20,682.9	70,918.2	1,188,865.4
USA	607.1	37,394.0	1,101.1	38,495.1	94,112.3	131,506.3	–	46,315.1[c]	178,922.5
Canada	–	10,032.8	2,284.4	12,317.2	27,001.0	37,033.8	–	2,798.8	42,117.0
Japan	–	117,234.0	6,348.9	123,582.9	106,491.2	223,725.2	4,260.1	9,744.6	244,078.8
OECD Europe	2,891.5	477,147.4	15,723.2	492,870.6	190,210.7	667,358.1	16,422.8	11,915.6	711,419.7
(EEC)	(1,903.7)	(403,275.4)	(9,765.3)	(413,040.7)	(167,829.9)	(571,105.3)	(7,974.8)	(8,859.5)	(597,704.9)
(Other OECD Europe)	(987.9)	(73,872.0)	(5,957.9)	(79,829.9)	(22,380.8)	(96,252.8)	(8,448.0)	(3,056.1)	(113,714.8)
OECD Oceania	–	11,236.6	–	11,236.6	946.7	12,183.3	–	144.1	12,327.4
Arab World	–	22,735.2	226.4	22,961.6	1,306.8	24,042.0	905.6	–	25,174.0
Bahrain	–	9,540.9	–	9,540.9	–	9,540.9	–	–	9,540.9
Democratic Yemen	–	1,471.5	–	1,471.5	1,306.8	2,778.3	–	–	2,778.3
Egypt	–	1,924.2	20.6	1,944.8	–	1,944.8	236.7	–	2,181.5
Jordan	–	795.4	–	795.4	–	795.4	–	–	795.4
Lebanon	–	2,469.6	–	2,469.6	–	2,469.6	–	–	2,469.6
Morocco	–	1,842.0	205.8	2,047.8	–	1,842.0	668.9	–	2,716.6
Saudi Arabia	–	540.2	–	540.2	–	540.2	–	–	540.2
Sudan	–	1,095.9	–	1,095.9	–	1,095.9	–	–	1,095.9
Syrian Arab Republic	–	1,776.1	–	1,776.1	–	1,776.1	–	–	1,776.1
Tunisia	–	867.4	–	867.4	–	867.4	–	–	867.4
Non-Arab Africa	–	8,262.9	–	8,262.9	17,174.0	25,436.9	154.4	1,502.3	27,093.6
Centrally Planned Europe	–	10,838.2	411.6	11,249.8	6,863.4	17,701.6	59,301.3	172.1	77,586.6
Other Countries	235.5	144,993.1	1,350.1	146,343.2	109,866.3	269,491.7	6,636.9	7,323.2	270,169.6
Bahamas (D)	–	6,225.5	–	6,225.5	7,532.3	13,757.8	–	1,594.9	15,352.7
Brazil	339.6	29,100.2	1,014.6	30,114.8	2,994.4	32,094.6	195.5	374.5	33,679.2
Guam (D)	–	987.8	–	987.8	144.1	1,131.9	–	566.0	1,697.9
India	–	7,511.7	–	7,511.7	6,709.1	14,220.8	833.5	–	15,054.3
Korea	–	14,797.0	–	14,797.0	1,162.8	15,959.8	–	–	15,959.8
Martinique (D)	–	288.2	–	288.2	205.8	494.0	–	41.1	535.1
Netherlands Antilles (D)	–	7,048.7	–	7,048.7	34,564.1	41,612.8	–	277.8	41,890.6
Philippines	–	8,345.2	–	8,345.2	41.2	8,386.4	102.9	318.9	8,808.2
Puerto Rico (D)	–	7,203.0	–	7,203.0	9,055.2	16,258.2	–	668.9	16,927.1
Singapore	–	16,803.5	–	16,803.5	5,680.1	22,483.6	–	1,173.1	23,656.7
Thailand	–	6,674.0	–	6,674.0	–	6,884.0	–	529.0	7,203.0
Trinidad	–	7,336.8	–	7,336.8	7,707.2	15,044.0	–	–	15,044.0
US Virgin Islands (D)	–	12,502.4	–	12,502.4	12,080.5	24,582.9	–	740.8	25,323.7
World	3,834.1	839,874.8	27,445.6	867,320.4	553,972.4	1,393,847.2	87,681.1	79,915.3	1,588,889.2

Table A2.6

The Arab World in International Crude Oil Movements, 1975 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	37,476.2	66,668.9	61,129.1	61,071.2	17,781.2	279,826.3	73,861.6	4,568.8	14,776.5	9,281.6
USA	12,697.9	102.9	319.0	15,887.8	4,373.3	30,324.6	8,736.2	–	1,769.9	–
Canada	154.4	1,718.4	1,502.3	566.0	82.3	9,682.9	1,759.6	–	668.9	–
Japan	267.5	4,682.0	21,557.6	2,366.7	72.0	65,146.0	22,740.9	226.4	6,585.6	–
OECD Europe	24,356.4	58,735.3	34,656.7	42,250.7	13,006.6	171,040.4	40,347.1	4,342.4	5,752.1	9,281.6
(EEC)	(22,123.5)	(40,151.6)	(31,981.3)	(36,467.8)	(11,792.3)	(138,966.5)	(33,277.9)	(3,406.0)	(4,970.1)	(7,913.0)
(Other OECD Europe)	(2,232.9)	(18,583.7)	(2,675.4)	(5,782.9)	(1,214.3)	(32,073.9)	(7,069.2)	(936.4)	(782.0)	(1,368.6)
OECD Oceania	–	1,430.3	2,994.4	–	247.0	3,632.4	277.8	–	–	–
Arab World	–	8,017.9	791.1	–	–	12,645.3	–	–	–	–
Bahrain	–	–	–	–	–	7,772.0	–	–	–	–
Democratic Yemen	–	936.4	298.4	–	–	–	–	–	–	–
Egypt	–	82.3	–	–	–	2,305.0	–	–	–	–
Jordan	–	–	–	–	–	884.9	–	–	–	–
Lebanon	–	1,459.9	–	–	–	730.6	–	–	–	–
Morocco	–	1,677.3	–	–	–	113.2	–	–	–	–
Saudi Arabia	–	–	492.7	–	–	–	–	–	–	–
Sudan	–	683.4	–	–	–	500.0	–	–	–	–
Syrian Arab Republic	–	2,483.0	–	–	–	–	–	–	–	–
Tunisia	–	695.6	–	–	–	339.6	–	–	–	–
Non-Arab Africa	339.6	1,986.0	–	411.6	1,255.4	4,126.3	710.0	–	–	–
Centrally Planned Europe	2,500.5	13,150.6	915.8	2,274.1	–	–	–	627.7	–	493.9
Other Countries	1,864.5	15,027.6	30,743.3	7,432.4	2,258.6	41,113.7	9,912.4	185.2	2,782.4	30.9
Bahamas (D)	154.4	–	–	3,385.4	–	1,131.9	1,029.0	–	–	–
Brazil	782.0	10,269.4	3,899.9	2,346.1	370.4	11,473.4	421.9	185.2	401.3	–
Guam (D)	–	–	–	–	308.7	576.2	–	–	–	–
India	–	2,181.5	–	–	–	4,157.2	–	–	–	–
Korea	–	–	8,252.6	–	–	6,369.5	–	–	–	–
Martinique (D)	247.0	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	–	–	–	–	1,430.3	–	–	–	–
Philippines	–	349.9	1,913.9	–	–	4,795.1	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	1,203.9	2,058.0	–	–	–
Singapore	–	1,286.3	7,711.3	–	–	2,490.2	957.0	–	1,039.3	–
Thailand	–	946.7	1,440.6	–	1,378.9	2,140.3	–	–	–	–
Trinidad	–	–	–	–	–	2,624.0	–	–	–	–
US Virgin Islands (D)	452.8	–	483.6	92.6	–	1,327.4	2,315.3	–	1,142.2	–
World	42,180.8	104,851.0	93,579.3	71,189.3	21,295.2	337,711.6	84,484.0	5,381.7	17,558.9	9,806.4

[a] The total export figure of 475,295.1 is subdivided into: Ecuador 7,460.3; Gabon 10,773.6; Indonesia 50,246.1; Iran 240,497.9; Nigeria 87,372.4; and Venezuela 78,944.9.

[b] Of which US imports from Canada 31,724.1.

Note:

A dash (—) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	4,856.9	597,814.5	33,483.9	631,298.3	374,113.5	971,928.0	31,559.4	62,700.5	1,099,671.7
USA	936.4	72,441.7	2,706.3	75,148.0	86,199.3	158,641.0	–	46,510.7[b]	207,858.0
Canada	–	15,465.9	688.9	16,154.8	24,397.6	39,863.5	–	2,079.1	42,631.5
Japan	–	116,832.7	6,812.0	123,644.7	94,225.5	211,058.2	8,602.4	2,377.0	228,849.6
OECD Europe	3,920.5	384,393.2	23,296.6	407,689.8	166,883.2	551,276.4	22,957.0	11,627.7	609,157.7
(EEC)	(2,860.6)	(314,760.9)	(19,149.7)	(333,910.6)	(142,197.5)	(456,958.4)	(11,535.1)	(10,341.4)	(497,984.6)
(Other OECD Europe)	(1,059.9)	(69,632.3)	(4,146.9)	(73,779.2)	(24,685.7)	(94,318.0)	(11,421.9)	(1,286.3)	(111,173.1)
OECD Oceania	–	8,581.9	–	8,581.9	2,407.9	10,989.8	–	185.1	11,174.9
Arab World	–	21,454.3	–	21,454.3	174.9	21,629.2	730.6	–	22,359.8
Bahrain	–	7,772.0	–	7,772.0	–	7,772.0	–	–	7,772.0
Democratic Yemen	–	1,234.8	–	1,234.8	–	1,234.8	–	–	1,234.8
Egypt	–	2,387.3	–	2,387.3	–	2,387.3	–	–	2,387.3
Jordan	–	884.9	–	884.9	–	884.9	–	–	884.9
Lebanon	–	2,190.5	–	2,190.5	–	2,190.5	–	–	2,190.5
Morocco	–	1,790.5	–	1,790.5	174.9	1,965.4	730.6	–	2,696.0
Saudi Arabia	–	492.7	–	492.7	–	492.7	–	–	492.7
Sudan	–	1,183.4	–	1,183.4	–	1,183.4	–	–	1,183.4
Syrian Arab Republic	–	2,483.0	–	2,483.0	–	2,483.0	–	–	2,483.0
Tunisia	–	1,035.2	–	1,035.2	–	1,035.2	–	–	1,035.2
Non-Arab Africa	–	8,828.9	–	8,828.9	18,964.5	27,793.4	61.7	576.2	28,431.3
Centrally Planned Europe	–	18,841.0	1,121.6	19,962.6	3,076.7	21,917.7	63,304.1	133.8	86,477.2
Other Countries	41.1	108,352.5	3,039.6	111,392.1	78,965.5	187,318.0	10,382.7	20,330.4	221,070.7
Bahamas (D)	–	5,546.3	–	5,546.3	3,313.4	8,859.7	–	1,430.3	10,290.0
Brazil	41.1	29,563.1	627.7	30,190.8	5,330.2	34,893.3	185.2	308.8	36,015.0
Guam (D)	–	884.9	–	884.9	–	884.9	–	339.6	1,224.5
India	–	4,157.2	–	4,157.2	6,688.5	10,845.7	1,008.4	2,212.3	14,066.4
Korea	–	14,622.1	–	14,622.1	1,811.0	16,433.1	–	–	16,433.1
Martinique (D)	–	247.0	–	247.0	298.4	545.4	–	–	545.4
Netherlands Antilles (D)	–	1,430.3	–	1,430.3	21,722.2	23,152.5	–	–	23,152.5
Philippines	–	7,058.9	–	7,058.9	1,203.9	8,262.8	514.5	627.8	9,405.1
Puerto Rico (D)	–	3,261.9	–	3,261.9	7,964.5	11,226.4	–	92.6	11,319.0
Singapore	–	12,444.8	1,039.3	13,484.1	3,591.2	16,042.2	–	1,035.1	18,110.4
Thailand	–	5,906.5	–	5,906.5	–	5,906.5	319.0	1,101.0	7,326.5
Trinidad	–	2,624.0	–	2,624.0	3,550.0	6,174.0	–	–	6,174.0
US Virgin Islands (D)	–	4,671.7	1,142.2	5,813.9	10,454.6	15,126.3	–	3,591.2	19,859.7
World	4,898.0	755,291.2	37,645.0	792,936.2	475,295.1	1,230,586.3	106,038.5	83,740.9	1,458,010.7

Table A2.7

The Arab World in International Crude Oil Movements, 1976 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	42,261.1	71,865.5	57,675.4	84,468.2	17,331.5	330,165.9	83,966.4	7,254.5	18,357.4	8,695.1
USA	21,022.5	1,584.7	607.1	23,502.4	4,517.3	62,707.3	13,232.9	874.7	2,984.1	–
Canada	257.3	1,471.5	277.8	1,150.0	–	5,875.6	617.4	113.2	1,121.6	–
Japan	82.3	6,842.9	20,950.4	2,047.7	72.0	79,500.5	27,422.9	–	7,614.6	–
OECD Europe	20,806.4	61,102.0	33,267.5	57,768.1	12,484.9	178,212.5	42,610.9	6,266.6	6,637.1	8,695.1
(EEC)	(18,995.3)	(43,897.1)	(29,439.7)	(46,027.2)	(11,349.9)	(141,210.0)	(33,236.7)	(5,114.1)	(6,503.3)	(8,643.6)
(Other OECD Europe)	(1,811.1)	(17,204.9)	(3,827.9)	(11,740.9)	(1,135.0)	(37,002.5)	(9,374.2)	(1,152.5)	(133.8)	(51.5)
OECD Oceania	92.6	864.4	2,572.5	–	257.3	3,869.0	82.3	–	–	–
Arab World	10.3	5,011.3	981.4	–	288.1	15,942.3	–	–	–	–
Bahrain	–	–	–	–	–	8,239.2	–	–	–	–
Democratic Yemen	–	–	277.8	–	288.1	1,389.2	–	–	–	–
Egypt	–	–	–	–	–	659.6	–	–	–	–
Jordan	–	–	–	–	–	1,202.9	–	–	–	–
Lebanon	–	1,821.3	–	–	–	514.5	–	–	–	–
Morocco	–	1,765.7	–	–	–	154.4	–	–	–	–
Saudi Arabia	–	–	703.6	–	–	–	–	–	–	–
Sudan	–	683.4	–	–	–	500.0	–	–	–	–
Syrian Arab Republic	–	168.8	–	–	–	2,675.4	–	–	–	–
Tunisia	10.3	572.1	–	–	–	607.1	–	–	–	–
Non-Arab Africa	339.6	504.2	–	82.3	2,016.8	3,138.5	720.3	–	–	–
Centrally Planned Europe	421.9	16,618.4	1,636.1	3,066.4	–	–	1,101.0	–	–	782.0
Other Countries	1,596.9	19,525.0	32,464.2	4,265.6	4,546.1	60,221.2	12,427.3	154.4	538.1	465.1
Bahamas (D)	–	–	–	1,574.4	–	1,584.7	761.5	–	–	–
Brazil	668.9	12,780.2	6,348.9	1,625.8	–	13,212.4	895.2	154.4	–	–
Guam (D)	–	–	41.2	–	514.5	905.5	82.3	–	–	–
India	–	473.3	10.3	–	–	4,496.7	1,059.9	–	–	–
Korea	–	–	8,304.0	–	–	8,499.5	–	–	–	–
Martinique (D)	51.5	–	–	–	–	185.2	–	–	–	–
Netherlands Antilles (D)	–	–	884.9	–	133.8	3,653.0	4,116.0	–	144.1	–
Philippines	–	668.9	2,768.0	–	–	3,251.6	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	1,029.0	2,644.5	–	195.5	–
Singapore	72.0	1,348.0	3,303.1	–	648.3	11,987.9	82.3	–	195.5	–
Thailand	–	421.9	710.0	–	2,305.0	3,056.1	411.6	–	–	–
Trinidad	–	–	–	–	–	5,721.2	339.6	–	–	–
US Virgin Islands (D)	504.2	3,832.7	987.8	483.6	586.5	339.6	411.6	–	–	463.1
World	44,629.8	113,524.4	92,757.1	91,882.5	24,182.5	409,467.9	98,215.0	7,408.8	18,895.5	9,942.2

[a]The total export figure of 525,297.1 is subdivided into: Ecuador 8,756.8; Gabon 10,248.8; Indonesia 60,988.8; Iran 268, 455.8; Nigeria 103,301.3; and Venezuela 73,645.5.

[b]Of which US imports from Canada 21,403.2.

Note:

A dash (–) indicates nil or negligible.

Importers \ Exporters	11 Tunisia	12 Arab Countries In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	3,560.3	687,734.0	37,867.3	725,601.3	384,516.7	1,072,250.7	42,847.6	66,697.8	1,219,663.4
USA	1,090.7	127,174.2	4,949.5	132,123.7	99,216.2	226,390.4	92.6	37,825.9[b]	269,258.4
Canada	–	9,649.6	1,234.8	10,884.4	26,116.0	35,765.6	144.1	486.0	37,630.5
Japan	–	136,918.7	7,614.6	144,533.3	76,454.7	213,373.4	6,318.1	11,010.3	238,316.4
OECD Europe	2,469.6	406,252.4	24,068.4	430,320.8	180,095.6	586,348.0	36,292.8	17,098.7	633,807.9
(EEC)	(1,348.0)	(324,155.9)	(21,609.0)	(345,764.9)	(148,073.1)	(472,229.0)	(21,629.6)	(15,521.4)	(534,143.6)
(Other OECD Europe)	(1,121.6)	(82,096.5)	(2,459.4)	(84,555.9)	(32,022.5)	(114,119.0)	(14,663.2)	(1,577.3)	(129,664.3)
OECD Oceania	–	7,738.1	–	7,738.1	2,634.2	10,372.3	–	277.9	10,650.2
Arab World	–	22,233.4	–	22,233.4	102.9	22,336.3	689.1	–	23,025.4
Bahrain	–	8,239.2	–	8,239.2	–	8,239.2	–	–	8,239.2
Democratic Yemen	–	1,955.1	–	1,955.1	–	1,955.1	–	–	1,955.1
Egypt	–	659.6	–	659.6	–	659.6	–	–	659.6
Jordan	–	1,202.9	–	1,202.9	–	1,202.9	–	–	1,202.9
Lebanon	–	2,335.8	–	2,335.8	–	2,335.8	–	–	2,335.8
Morocco	–	1,920.1	–	1,920.1	102.9	2,023.0	689.1	–	2,712.4
Saudi Arabia	–	703.6	–	703.6	–	703.6	–	–	703.6
Sudan	–	1,183.4	–	1,183.4	–	1,183.4	–	–	1,183.4
Syrian Arab Republic	–	2,844.2	–	2,844.2	–	2,844.2	–	–	2,844.2
Tunisia	–	1,189.5	–	1,189.5	–	1,189.5	–	–	1,189.5
Non-Arab Africa	133.8	6,801.7	133.8	6,935.5	19,046.8	25,848.5	144.1	1,214.1	27,340.5
Centrally Planned Europe	–	22,843.8	782.0	23,625.8	4,074.8	26,918.6	66,130.0	1,917.9	95,748.5
Other Countries	99.8	135,046.3	1,257.4	136,303.7	117,655.9	252,702.2	12,753.4	15,267.6	281,980.5
Bahamas (D)	–	4,120.6	–	4,120.6	5,093.6	9,214.2	–	304.1	9,518.3
Brazil	–	35,531.4	154.4	35,685.8	6,081.4	41,612.8	144.1	277.7	42,189.0
Guam (D)	–	1,543.5	–	1,543.5	–	1,543.5	–	–	1,543.5
India	–	6,040.2	–	6,040.2	7,367.6	13,407.8	1,029.0	–	14,436.9
Korea	–	16,803.5	–	16,803.5	2,027.1	18,830.6	–	–	18,830.7
Martinique (D)	–	236.7	–	236.7	236.7	473.4	–	–	473.4
Netherlands Antilles (D)	–	8,787.7	144.1	8,931.8	26,517.3	35,305.0	–	2,685.6	38,134.7
Philippines	–	6,688.5	–	6,688.5	1,934.5	8,623.0	576.2	638.0	9,837.2
Puerto Rico (D)	–	3,673.5	195.5	3,869.0	8,540.7	12,214.2	–	1,636.2	14,045.9
Singapore	–	17,441.6	195.5	17,637.1	2,696.0	20,137.6	–	1,543.4	21,876.5
Thailand	–	6,904.6	–	6,904.6	41.2	6,945.8	174.9	524.8	7,645.5
Trinidad	–	6,060.8	–	6,060.8	5,803.6	11,864.4	–	–	11,864.4
US Virgin Islands (D)	99.8	7,146.0	562.9	7,708.9	19,777.4	27,391.9	–	3,383.7	30,870.0
World	3,793.9	874,659.2	40,040.4	914,699.6	525,397.1	1,400,056.3	122,564.2	85,097.4	1,647,758.3

Table A2.8

The Arab World in International Crude Oil Movements, 1977 (thousand toe).

Exporters / Importers	1 Algeria	2 Iraq	3 Kuwait	4 Libyan Arab Jamahiriya	5 Qatar	6 Saudi Arabia	7 United Arab Emirates	8 Egypt	9 Oman	10 Syrian Arab Republic
OECD Countries	47,292.9	78,091.0	56,124.2	90,222.7	11,833.5	345,774.9	87,053.4	8,036.5	15,836.2	7,295.6
USA	26,167.5	3,725.0	2,140.3	38,968.2	3,292.8	69,838.2	16,536.0	1,399.4	3,817.6	–
Canada	257.3	946.7	205.8	–	–	7,954.2	247.0	329.3	–	–
Japan	164.6	7,666.1	18,851.3	1,008.4	1,800.8	87,712.0	27,474.3	–	9,003.6	–
OECD Europe	20,703.5	64,569.8	33,123.5	50,246.1	6,246.0	174,960.9	42,508.0	6,307.8	3,015.0	7,295.6
(EEC)	(18,244.2)	(46,407.9)	(30,993.5)	(40,933.6)	(5,299.4)	(144,152.6)	(34,358.3)	(5,711.0)	(1,101.0)	(6,678.2)
(Other OECD Europe)	(2,459.3)	(18,161.9)	(2,130.0)	(9,312.5)	(946.6)	(30,808.3)	(8,149.7)	(596.8)	(1,914.0)	(617.4)
OECD Oceania	–	1,183.4	1,821.3	–	493.9	5,309.6	288.1	–	–	–
Arab World	–	4,518.6	1,191.1	–	51.5	17,279.8	–	–	–	–
Bahrain	–	–	–	–	–	10,269.4	–	–	–	–
Democratic Yemen	–	923.0	411.6	–	51.5	185.2	–	–	–	–
Egypt	–	–	–	–	–	–	–	–	–	–
Jordan	–	–	–	–	–	1,215.2	–	–	–	–
Lebanon	–	226.4	–	–	–	1,564.1	–	–	–	–
Morocco	–	1,677.3	–	–	–	391.0	–	–	–	–
Saudi Arabia	–	–	779.5	–	–	–	–	–	–	–
Sudan	–	776.0	–	–	–	500.0	–	–	–	–
Syrian Arab Republic	–	360.2	–	–	–	2,640.4	–	–	–	–
Tunisia	–	555.7	–	–	–	514.5	–	–	–	–
Non-Arab Africa	360.2	1,276.0	102.9	–	545.4	2,551.9	833.5	–	154.4	–
Centrally Planned Europe	339.6	15,311.5	926.1	2,243.2	–	–	915.8	133.8	–	883.9
Other Countries	840.6	17,042.9	24,727.9	3,832.0	8,851.4	74,887.8	10,840.5	2,119.7	1,173.1	–
Bahamas (D)	–	–	–	2,130.0	–	6,966.3	236.7	–	–	–
Brazil	–	11,720.3	6,204.9	1,389.2	–	13,634.3	247.0	–	–	–
Guam (D)	–	–	–	–	524.8	905.5	–	–	–	–
India	–	–	–	–	–	2,953.2	987.8	–	–	–
Korea	–	463.1	7,007.5	–	–	11,668.9	–	–	–	–
Martinique (D)	–	–	–	–	–	–	–	–	–	–
Netherlands Antilles (D)	–	–	–	–	432.2	802.6	2,634.2	–	133.6	–
Philippines	–	1,131.9	1,934.5	–	–	3,395.7	–	–	–	–
Puerto Rico (D)	–	–	–	–	–	1,605.2	–	1,667.0	936.4	–
Singapore	–	2,315.3	1,214.2	–	154.4	11,658.6	195.5	–	–	–
Thailand	–	–	567.0	–	2,418.2	4,023.4	51.5	–	–	–
Trinidad	473.3	–	–	–	–	2,387.3	2,160.9	–	–	–
US Virgin Islands (D)	–	–	–	–	5,217.0	1,059.9	2,613.7	–	–	–
World	48,833.3	116,240.0	83,072.2	96,297.9	21,281.8	440,494.4	99,643.2	10,290.0	17,163.7	8,179.5

*This column also includes an additional figure of 13,398.0 thousand toes representing crude exports from Bahrain to Saudi Arabia in 1977.

[a]The total export figure of 510,775.0 is subdivided into: Ecuador 7,192.7; Gabon 9,384.5; Indonesia 70,002.9; Iran 249,954.4; Nigeria 103,167.5; and Venezuela 71,073.0.

[b]Of which US imports from Canada 14,982.2.

Note:

A dash (—) indicates nil or negligible.

Exporters / Importers	11 Tunisia	12 Arab Countries* In OPEC (1+...+7)	13 Non-OPEC Arab Countries (8+...+11)	14 Arab World (12+13)	15 Non-Arab OPEC Countries[a]	16 OPEC Countries (12+15)	17 Centrally Planned Economies	18 Other World	19 Total (14+15+17+18)
OECD Countries	4,265.2	716,392.6	35,433.5	751,826.1	384,372.8	1,100,765.4	45,430.4	81,581.4	1,263,210.7
USA	1,399.4	160,668.0	6,616.4	167,284.4	128,532.4	290,200.4	92.6	39,513.7[b]	335,423.1
Canada	–	9,611.0	329.3	9,940.3	21,218.0	30,829.0	247.0	3,189.7	34,595.0
Japan	–	144,677.5	9,003.6	153,681.1	74,551.1	219,228.6	7,285.3	11,936.4	247,453.9
OECD Europe	2,865.7	392,357.8	19,484.1	411,842.0	157,961.8	550,319.6	37,754.0	26,563.6	634,121.3
(EEC)	(1,872.8)	(320,389.5)	(15,363.0)	(335,752.5)	(128,635.3)	(449,024.8)	(22,926.1)	(19,581.8)	(508,895.7)
(Other OECD Europe)	(992.9)	(71,968.3)	(4,121.1)	(76,089.4)	(29,326.5)	(101,294.8)	(14,827.9)	(6,981.8)	(127,225.6)
OECD Oceania	–	9,096.3	–	9,096.3	2,109.5	11,205.8	51.5	360.1	11,617.4
Arab World	–	36,439.0	–	36,439.0	113.2	36,552.2	1,152.5	–	37,704.7
Bahrain	–	10,269.4	–	10,269.4	–	10,269.4	–	–	10,269.4
Democratic Yemen	–	1,571.3	–	1,571.3	–	1,571.3	401.3	–	1,972.6
Egypt	–	–	–	–	–	–	–	–	–
Jordan	–	1,215.2	–	1,215.2	–	1,215.2	–	–	1,215.2
Lebanon	–	1,790.5	–	1,790.5	–	1,790.5	–	–	1,790.5
Morocco	–	2,068.3	–	2,068.3	113.2	2,181.5	751.2	–	2,932.7
Saudi Arabia	–	779.5	–	779.5	–	779.5	–	–	779.5
Sudan	–	1,276.0	–	1,276.0	–	1,276.0	–	–	1,276.0
Syrian Arab Republic	–	3,000.6	–	3,000.6	–	3,000.6	–	–	3,000.6
Tunisia	–	1,070.2	–	1,070.2	–	1,070.2	–	–	1,070.2
Non-Arab Africa	–	5,669.9	154.4	5,824.3	20,518.3	26,188.2	236.7	1,409.5	27,988.8
Centrally Planned Europe	–	19,736.2	1,017.7	20,753.9	6,400.4	26,136.6	73,203.1	1,647.4	102,004.8
Other Countries	–	141,023.1	3,292.8	144,315.9	99,370.3	240,393.4	13,819.3	4,074.4	261,579.9
Bahamas (D)	–	9,333.0	–	9,333.0	216.1	9,549.1	–	226.4	9,775.5
Brazil	–	33,195.7	–	33,195.7	15,887.8	49,083.5	–	–	49,083.5
Guam (D)	–	1,430.3	–	1,430.3	–	1,430.3	–	102.9	1,533.2
India	–	3,941.0	–	3,941.0	4,838.2	18,779.2	1,697.9	4,145.0	14,622.1
Korea	–	19,139.5	–	19,139.5	2,202.1	21,341.6	–	–	21,341.5
Martinique (D)	–	–	–	–	524.8	524.8	–	–	524.8
Netherlands Antilles (D)	–	3,869.0	133.8	4,002.8	25,303.1	29,172.1	–	648.3	29,820.4
Philippines	–	6,462.1	–	6,462.1	2,068.3	8,530.4	771.8	503.8	9,806.4
Puerto Rico (D)	–	1,605.2	2,603.4	4,208.6	4,784.9	6,390.1	–	2,171.2	11,164.7
Singapore	–	15,538.0	–	15,538.0	8,427.5	23,965.5	–	349.8	24,315.3
Thailand	–	7,060.1	–	7,060.1	–	7,060.1	236.7	1,141.0	8,437.8
Trinidad	–	5,021.5	–	5,021.5	3,642.7	8,664.2	–	514.2	9,178.7
US Virgin Islands (D)	–	8,890.6	–	8,890.6	9,086.1	17,976.7	–	7,768.9	25,745.6
World	4,265.2	919,260.8	39,898.4	959,159.2	510,775.0	1,430,035.8	133,842.0	88,712.7	1,692,488.9

Table A2.9

Crude Oil Imports of the OECD Area by Source, 1960-1977 (Mtoe).

Imported from:	1960	1965	1970	1974	1975	1976	1977
OECD area	7.12	16.57	38.49	46.24	42.04	34.49	44.16
Africa	9.72	94.28	254.16	214.64	199.78	238.05	248.02
Algeria	–	23.72	44.65	35.33	39.68	43.20	48.32
Libyan Arab Jamahiriya	–	54.70	157.99	66.35	58.12	86.82	91.09
Middle East	180.33	283.53	487.15	774.96	737.19	807.53	821.38
Iraq	38.70	50.94	59.35	57.63	71.44	73.30	78.27
Kuwait	72.64	85.57	105.17	83.45	61.66	52.00	56.19
Saudi Arabia	36.18	60.01	122.88	294.41	270.72	319.77	343.83
Far East	9.57	10.51	27.25	61.42	63.39	73.69	83.38
USSR & other Eastern Europe	7.59	14.36	25.00	16.71	20.14	30.14	34.42
Other	55.57	65.67	57.65	53.16	64.12	53.24	56.76
Venezuela	50.22	59.51	61.01	46.19	49.96	39.97	37.24
Unallocated	0.10	–	0.10	0.14	3.60	2.55	2.53
Total	262.81	468.34	852.58	1,121.04	1,088.24	1,205.20	1,246.50

Note:

A dash (–) indicates nil or negligible.

Table A2.10

The Arab World in World Exports of Petroleum Products to OECD Countries, 1973 (Mtoe).

Exporters / Importers	1 Algeria	2 Bahrain	3 Kuwait	4 Libyan Arab Jamahiriya	5 Saudi Arabia	6 Other Arab Countries	7 Arab World (1+...+6)	8 Non-Arab OPEC Countries	9 Centrally Planned Economies	10 OECD Area	11 Other World	12 Total (7+...+11)
OECD Countries	1.8	4.3	3.9	2.1	3.9	0.9	16.9	58.4	26.2	153.8	89.9	345.1
USA	0.8	0.6	0.2	1.8	0.8	0.1	4.3	42.8	1.6	24.0	75.8	148.5
Canada	–	–	–	–	–	–	–	2.5	–	2.1	2.3	6.9
Japan	–	1.0	2.8	–	1.8	–	5.6	9.9	0.9	3.8	5.3	25.5
OECD Europe	0.9	1.2	0.7	0.3	1.1	0.8	5.0	2.4	23.7	123.0	5.2	159.3
(EEC)	(0.8)	(1.1)	(0.7)	(0.2)	(0.6)	(0.6)	(4.0)	(1.8)	(15.1)	(90.7)	(3.9)	(115.5)
(Other OECD Europe)	(0.1)	(0.1)	(–)	(0.1)	(0.5)	(0.2)	(1.0)	(0.6)	(8.6)	(32.3)	(1.3)	(43.8)
OECD Oceania	0.1	1.5	0.2	–	0.2	–	2.0	0.8	–	0.9	1.3	4.9

Note:

A dash (–) indicates nil or negligible.

Table A2.11

The Arab World in World Exports of Petroleum Products to OECD Countries, 1974 (Mtoe).

Exporters / Importers	1 Algeria	2 Bahrain	3 Kuwait	4 Libyan Arab Jamahiriya	5 Saudi Arabia	6 Other Arab Countries	7 Arab World (1 + . . . + 6)	8 Non-Arab OPEC Countries	9 Centrally Planned Economies	10 OECD Area	11 Other World	12 Total (7 + . . . + 11)
OECD Countries	1.3	5.7	3.7	0.3	6.1	1.8	18.9	48.0	29.3	129.3	89.0	314.5
USA	0.5	0.6	–	–	0.9	0.3	2.3	36.1	1.4	17.0	73.8	130.6
Canada	–	–	–	–	–	–	–	1.7	0.1	1.6	1.4	4.8
Japan	–	3.7	2.7	–	3.4	0.2	10.0	6.8	1.2	2.5	8.1	28.6
OECD Europe	0.7	1.4	1.0	0.3	1.8	1.2	6.4	3.3	26.6	107.9	4.9	149.1
(EEC)	(0.4)	(1.3)	(0.9)	(0.2)	(1.1)	(1.1)	(5.0)	(2.8)	(16.7)	(77.8)	(3.8)	(106.1)
(Other OECD Europe)	(0.3)	(0.1)	(0.1)	(0.1)	(0.7)	(0.1)	(1.4)	(0.5)	(9.9)	(30.1)	(1.1)	(43.0)
OECD Oceania	0.1	–	–	–	–	0.1	0.2	0.1	–	0.3	0.8	1.4

Note:

A dash (–) indicates nil or negligible.

Table A2.12

The Arab World in World Exports of Petroleum Products to OECD Countries, 1975 (Mtoe).

Exporters / Importers	1 Algeria	2 Bahrain	3 Kuwait	4 Libyan Arab Jamahiriya	5 Saudi Arabia	6 Other Arab Countries	7 Arab World (1 +...+ 6)	8 Non-Arab OPEC Countries	9 Centrally Planned Economies	10 OECD Area	11 Other World	12 Total (7 +...+ 11)
OECD Countries	1.7	3.4	4.6	0.9	4.9	3.5	19.0	26.5	33.3	118.3	95.8	292.9
USA	0.9	0.8	0.6	0.5	0.4	0.3	3.5	17.9	1.7	12.1	70.1	105.3
Canada	–	–	–	–	–	–	–	0.7	–	1.1	0.5	2.3
Japan	–	0.1	2.3	–	3.8	1.7	7.9	3.8	4.8	2.1	0.8	19.4
OECD Europe	0.8	1.3	1.2	0.4	0.7	1.4	5.8	3.6	26.8	102.4	22.4	161.0
(EEC)	(0.7)	(1.1)	(1.1)	(0.4)	(0.5)	(1.2)	(5.0)	(2.9)	(15.2)	(75.7)	(15.3)	(114.1)
(Other OECD Europe)	(0.1)	(0.2)	(0.1)	(–)	(0.2)	(0.2)	(0.8)	(0.7)	(11.6)	(26.7)	(7.1)	(46.9)
OECD Oceania	–	1.2	0.5	–	–	0.1	1.8	0.5	–	0.6	2.0	4.9

Note:

A dash (–) indicates nil or negligible.

Table A2.13

The Arab World in World Exports of Petroleum Products to OECD Countries, 1976 (Mtoe).

Exporters / Importers	1 Algeria	2 Bahrain	3 Kuwait	4 Libyan Arab Jamahiriya	5 Saudi Arabia	6 Other Arab Countries	7 Arab World (1 +...+ 6)	8 Non-Arab OPEC Countries	9 Centrally Planned Economies	10 OECD Area	11 Other World	12 Total (7 +...+ 11)
OECD Countries	1.7	4.4	6.0	1.2	7.1	2.3	22.7	38.0	36.0	116.4	51.9	265.0
USA	1.1	0.2	0.2	0.6	0.2	0.3	2.6	26.9	1.6	12.2	36.1	79.4
Canada	–	–	–	–	–	–	–	0.9	–	1.0	0.1	2.0
Japan	–	1.8	3.0	–	5.4	0.4	10.6	4.9	0.9	2.4	6.4	25.2
OECD Europe	0.6	1.2	2.1	0.6	1.4	1.5	7.4	4.9	33.5	100.3	7.8	153.9
(EEC)	(0.6)	(1.2)	(1.8)	(0.4)	(0.8)	(1.4)	(6.2)	(3.5)	(19.8)	(77.2)	(4.8)	(111.5)
(Other OECD Europe)	(–)	(–)	(0.3)	(0.2)	(0.6)	(0.1)	(1.2)	(1.4)	(13.7)	(23.1)	(3.0)	(42.4)
OECD Oceania	–	1.2	0.7	–	0.1	0.1	2.1	0.4	–	0.5	1.5	4.5

Note:

A dash (–) indicates nil or negligible.

Table A2.14

The Arab World in World Exports of Petroleum Products to OECD Countries, 1977 (Mtoe).

	1	2	3	4	5	6	7	8	9	10	11	12
Exporters / Importers	Algeria	Bahrain	Kuwait	Libyan Arab Jamahiriya	Saudi Arabia	Other Arab Countries	Arab World (1 + . . . + 6)	Non-Arab OPEC Countries	Centrally Planned Economies	OECD Area	Other World	Total (7 + . . . + 11)
OECD Countries	1.4	4.7	5.8	2.7	7.3	2.1	23.9	38.4	38.2	129.7	48.0	278.2
USA	0.7	0.8	0.3	1.1	0.3	–	3.0	27.7	1.5	17.2	35.0	84.4
Canada	–	–	–	–	–	–	–	0.7	–	1.6	1.0	3.3
Japan	–	2.0	2.9	–	5.8	0.1	10.9	5.8	0.6	3.4	5.2	25.9
OECD Europe	0.7	0.8	1.7	1.6	1.2	1.9	7.9	4.1	36.1	106.4	5.0	159.5
(EEC)	(0.4)	(0.4)	(1.6)	(0.8)	(0.8)	(1.6)	(5.6)	(2.5)	(18.4)	(79.9)	(5.0)	(111.4)
(Other OECD Europe)	(0.3)	(0.4)	(0.1)	(0.8)	(0.4)	(0.3)	(2.3)	(1.6)	(17.7)	(26.5)	(–)	(48.1)
OECD Oceania	–	1.1	0.9	–	–	0.1	2.1	0.1	–	1.1	1.8	5.1

Note:

A dash (–) indicates nil or negligible.

APPENDIX THREE

ARAB AND WORLD CRUDE PETROLEUM RESERVES AND PRODUCTION, 1954 - 1979

Table A3.1

World Crude Oil Reserves as of 1 January, 1954-1980 (Bb, percentage).*

	1954		1955		1956		1957		1958		1959		1960	
Arab Countries	63.2	46.7	82.5	52.4	99.5	52.7	114.6	49.6	137.3	52.0	144.7	52.4	153.2	52.3
Algeria	–	–	–	–	–	–	–	–	0.5	0.2	3.5	1.3	5.0	1.7
Bahrain	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
Egypt	0.1	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.3	0.1	0.4	0.1	0.5	0.2
Iraq	13.0	9.6	14.3	9.0	20.0	10.6	22.0	9.5	25.0	9.5	25.0	9.1	25.0	8.5
Kuwait	20.2	14.9	30.2	19.0	40.3	21.3	50.3	21.8	62.2	23.6	63.0	22.8	65.3	22.3
Libyan Arab Jamahiriya	–	–	–	–	–	–	–	–	–	–	0.1	–	1.5	0.5
Morocco	–	–	–	–	0.1	0.1	–	–	–	–	–	–	–	–
Oman	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Qatar	1.5	1.1	1.5	1.0	1.5	0.8	1.5	0.7	1.8	0.6	2.5	0.9	2.5	0.8
Saudi Arabia	28.1	20.8	36.2	23.0	37.2	19.7	40.3	17.4	47.3	17.9	50.0	18.1	53.2	18.2
Syrian Arab Republic	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunisia	–	–	–	–	–	–	–	–	–	–	–	–	–	–
United Arab Emirates	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Abu Dhabi)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	27.4	20.2	27.8	17.7	41.3	21.9	48.2	20.9	55.5	21.0	58.0	21.1	62.0	21.1
Iran	15.0	11.1	15.0	9.5	27.0	14.3	30.0	13.0	32.0	12.1	33.0	12.0	35.0	11.9
Nigeria	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Venezuela	9.9	7.3	10.9	7.0	12.0	6.4	13.2	5.7	16.0	6.1	16.5	6.0	18.0	6.1
Indonesia	2.5	1.8	1.9	1.2	2.3	1.2	5.0	2.2	7.5	2.8	8.5	3.1	9.0	3.1
OECD Countries	31.4	23.2	32.6	20.7	35.4	18.8	37.7	16.3	38.3	14.5	38.5	14.0	39.7	13.5
USA	28.9	21.4	29.6	18.8	31.2	16.6	32.9	14.2	33.0	12.5	33.0	12.0	33.5	11.4
Canada	2.0	1.4	2.2	1.4	2.8	1.5	3.5	1.5	4.0	1.5	4.0	1.5	4.6	1.6
Japan	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–
EEC	0.4	0.3	0.7	0.5	0.9	0.5	0.9	0.4	0.9	0.3	1.1	0.4	1.2	0.4
(United Kingdom)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Others)	(0.4)	(0.3)	(0.7)	(0.5)	(0.9)	(0.5)	(0.9)	(0.4)	(0.9)	(0.3)	(1.1)	(0.4)	(1.2)	(0.4)
Other OECD Europe	0.1	0.1	0.1	–	0.5	0.2	0.4	0.2	0.4	0.2	0.4	0.1	0.3	0.1
OECD Oceania	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mexico	1.7	1.3	1.8	1.1	1.9	1.0	2.5	1.1	2.7	1.0	2.5	0.9	2.5	0.9
USSR	9.0	6.7	9.5	6.0	10.0	5.3	23.5	10.2	24.5	9.3	26.0	9.4	28.0	9.6
China	–	–	–	–	–	–	0.7	0.3	0.8	0.3	0.5	0.2	0.9	0.3
Other Countries	2.6	1.9	3.3	2.1	0.7	0.3	3.8	1.6	4.9	1.9	5.5	2.0	6.7	2.3
World Total	135.3	100.0	157.5	100.0	188.8	100.0	231.0	100.0	264.0	100.0	275.0	100.0	293.0	100.0

*For each year, the figures are, in billion barrels under the first column and a percentage of the world total under the second column.

Note:

A dash (–) indicates nil or negligible.

Sources: Oil and Gas Journal (Annual Worldwide Reports), American Petroleum Institute (for the reserve estimates of the USA), Canadian Petroleum Association (for the reserve estimates of Canada), and official information.

	1961		1962		1963		1964		1965		1966	
Arab Countries	155.6	51.7	160.3	51.3	168.5	53.8	185.5	56.1	191.1	56.4	194.5	55.9
Algeria	5.2	1.7	5.5	1.8	6.5	2.1	7.0	2.1	7.5	2.2	7.4	2.1
Bahrain	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
Egypt	0.6	0.2	0.7	0.2	0.7	0.2	1.5	0.5	1.5	0.4	2.0	0.6
Iraq	27.0	9.0	26.5	8.6	26.0	8.3	25.5	7.7	25.0	7.4	25.0	7.2
Kuwait	65.0	21.6	66.5	21.0	66.7	21.3	68.5	20.7	69.0	20.4	68.7	19.7
Libyan Arab Jamahiriya	2.0	0.7	3.0	1.0	4.5	1.5	7.0	2.1	9.0	2.7	10.0	2.9
Morocco	–	–	–	–	–	–	–	–	–	–	–	–
Oman	–	–	–	–	–	–	–	–	0.5	0.1	0.5	0.1
Qatar	2.5	0.8	2.8	0.9	3.0	0.9	3.0	0.9	3.5	0.1	3.0	0.9
Saudi Arabia	53.0	17.6	55.0	17.7	55.8	17.8	65.0	19.6	66.7	19.7	66.2	19.0
Syrian Arab Republic	0.1	–	0.1	–	0.1	–	0.3	0.1	0.5	0.1	1.2	0.3
Tunisia	–	–	–	–	–	–	–	–	–	–	0.3	0.1
United Arab Emirates	–	–	–	–	5.0	1.6	7.5	2.3	7.7	2.3	10.0	2.9
(Abu Dhabi)	(–)	(–)	(–)	(–)	(5.0)	(1.6)	(7.5)	(2.3)	(7.7)	(2.3)	(10.0)	(2.9)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	63.1	21.0	62.3	20.1	64.4	20.5	64.5	19.5	66.0	19.5	69.8	20.0
Iran	35.6	11.6	35.0	11.3	37.0	11.8	37.0	11.2	38.0	11.2	40.0	11.5
Nigeria	0.1	0.1	0.3	0.1	0.4	0.1	0.5	0.2	1.0	0.3	3.0	0.9
Venezuela	18.5	6.2	17.5	5.7	17.0	5.4	17.0	5.1	17.0	5.0	17.3	4.9
Indonesia	9.5	3.1	9.5	3.0	10.0	3.2	10.0	3.0	10.0	3.0	9.5	2.7
OECD Countries	40.2	13.4	42.2	13.6	41.7	13.3	42.2	12.7	39.8	11.7	40.5	11.6
USA	33.5	11.2	35.5	11.5	35.3	11.3	34.3	10.3	31.0	9.2	31.3	9.0
Canada	5.0	1.7	5.0	1.6	4.6	1.5	5.7	1.7	6.2	1.8	6.7	1.9
Japan	0.1	–	0.1	–	0.1	–	0.1	–	–	–	–	–
EEC	1.3	0.4	1.3	0.4	1.3	0.4	1.4	0.4	1.5	0.4	1.6	0.4
(United Kingdom)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Others)	(1.3)	(0.4)	(1.3)	(0.4)	(1.3)	(0.4)	(1.4)	(0.4)	(1.5)	(0.4)	(1.6)	(0.4)
Other OECD Europe	0.3	0.1	0.3	0.1	0.3	0.1	0.6	0.2	1.0	0.3	0.8	0.2
OECD Oceania	–	–	–	–	0.1	–	0.1	0.1	0.1	–	0.1	–
Mexico	2.3	0.7	2.5	0.8	2.5	0.8	2.5	0.8	2.8	0.8	2.5	0.7
USSR	31.5	10.5	32.5	10.5	28.5	9.1	28.0	8.4	29.3	8.7	32.0	9.2
China	0.8	0.2	0.5	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1
Other Countries	7.5	2.5	9.7	3.6	7.6	2.4	8.0	2.4	9.4	2.8	8.5	2.5
World Total	301.0	100.0	310.0	100.0	313.5	100.0	331.0	100.0	338.7	100.0	348.1	100.0

Table A3.1 (continued)

World Crude Oil Reserves as of 1 January, 1954-1980 (Bb, percentage).*

	1967		1968		1969		1970		1971		1972		1973	
Arab Countries	218.9	57.4	242.5	59.5	255.7	56.2	326.3	61.5	338.1	55.3	353.2	55.8	373.9	56.3
Algeria	7.3	1.9	6.9	1.7	7.0	1.5	8.0	1.5	30.0	4.9	12.3	1.9	47.0	7.1
Bahrain	0.2	0.1	0.2	0.1	0.2	–	0.3	0.1	0.6	0.1	0.6	0.1	0.4	0.1
Egypt	0.9	0.3	1.4	0.3	2.1	0.5	5.0	0.9	4.5	0.7	4.0	0.6	5.2	0.8
Iraq	24.0	6.3	23.5	5.8	28.0	6.2	27.2	5.2	32.0	5.2	36.0	5.7	29.0	4.4
Kuwait	75.2	19.7	76.8	18.7	76.5	16.8	74.5	14.0	80.0	13.1	78.2	12.4	72.9	11.0
Libyan Arab Jamahiriya	20.2	5.2	29.2	7.2	30.0	6.6	35.0	6.6	29.2	4.8	25.0	4.0	30.4	4.6
Morocco	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oman	0.5	0.1	2.5	0.6	2.5	0.5	5.0	0.9	1.7	0.3	5.2	0.8	5.0	0.7
Qatar	4.0	1.0	3.7	0.9	3.9	0.9	5.5	1.0	4.3	0.7	6.0	0.9	7.0	1.0
Saudi Arabia	72.5	19.0	81.4	20.0	84.5	18.6	146.5	27.6	141.3	23.1	157.5	25.0	146.0	22.0
Syrian Arab Republic	1.5	0.4	1.5	0.4	1.5	0.3	1.5	0.3	1.2	0.2	7.3	1.1	7.2	1.1
Tunisia	0.3	0.1	0.4	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.6	0.1	1.0	0.1
United Arab Emirates	12.5	3.3	15.0	3.7	19.0	4.2	17.0	3.2	12.8	2.1	20.5	3.2	22.8	3.4
(Abu Dhabi)	(12.5)	(3.3)	(15.0)	(3.7)	(18.0)	(4.0)	(16.0)	(3.0)	(11.8)	(1.9)	(18.9)	(3.0)	(20.8)	(3.1)
(Dubai)	(–)	(–)	(–)	(–)	(1.0)	(0.2)	(1.0)	(0.2)	(1.0)	(0.2)	(1.6)	(0.2)	(2.0)	(0.3)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	74.2	19.4	73.3	18.0	82.4	18.1	83.8	15.8	103.3	16.9	91.5	14.5	103.8	15.6
Iran	44.2	11.6	43.0	10.7	54.0	11.9	55.0	10.4	70.0	11.5	55.5	8.8	65.0	9.8
Nigeria	3.5	0.9	3.5	0.9	4.0	0.9	5.0	0.9	9.3	1.5	11.7	1.9	15.0	2.2
Venezuela	17.4	4.5	17.0	4.2	15.5	3.4	14.8	2.8	14.0	2.3	13.9	2.2	13.8	2.1
Indonesia	9.1	2.4	9.0	2.2	8.9	1.9	9.0	1.7	10.0	1.6	10.4	1.6	10.0	1.5
OECD Countries	42.6	11.1	42.6	10.4	44.0	9.7	42.9	8.1	53.8	8.8	64.0	10.1	55.6	8.4
USA	31.5	8.2	31.4	7.7	30.7	6.7	29.6	5.6	39.0	6.4	38.1	6.0	36.3	5.5
Canada	7.8	2.0	8.2	2.0	8.4	1.9	8.6	1.6	8.6	1.4	8.3	1.3	8.0	1.2
Japan	–	–	–	–	–	–	–	–	–	–	–	–	–	–
EEC	1.5	0.4	1.6	0.4	1.5	0.3	1.4	0.3	2.2	0.3	6.7	1.1	6.2	0.9
(United Kingdom)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(1.0)	(0.2)	(5.0)	(0.8)	(5.0)	(0.7)
(Others)	(1.5)	(0.4)	(1.6)	(0.4)	(1.5)	(0.3)	(1.4)	(0.3)	(1.2)	(0.1)	(1.7)	(0.3)	(1.2)	(0.2)
Other OECD Europe	1.2	0.3	1.0	0.2	0.9	0.2	0.8	0.1	1.8	0.3	7.8	1.2	2.7	0.4
OECD Oceania	0.6	0.2	0.4	0.1	2.5	0.6	2.5	0.5	2.2	0.4	3.1	0.5	2.4	0.4
Mexico	2.5	0.6	2.6	0.6	5.5	1.2	6.0	1.1	3.2	0.5	4.5	0.7	2.8	0.4
USSR	32.5	8.5	34.5	8.5	40.0	8.8	53.0	10.0	77.0	12.6	75.0	11.9	75.0	11.3
China	0.3	0.1	0.3	0.1	15.0	3.3	15.0	2.8	20.0	3.3	20.0	3.2	19.5	2.9
Other Countries	10.9	2.9	11.7	2.9	12.1	2.7	3.5	0.7	15.8	2.6	24.4	3.8	33.6	5.1
World Total	381.9	100.0	407.5	100.0	454.7	100.0	530.5	100.0	611.2	100.0	632.6	100.0	664.2	100.0

*For each year, the figures are, in billion barrels under the first column and a percentage of the world total under the second column.

Note:

A dash (–) indicates nil or negligible.

Sources: Oil and Gas Journal (Annual Worldwide Reports), American Petroleum Institute (for the reserve estimates of the USA), Canadian Petroleum Association (for the reserve estimates of Canada), and official information.

	1974		1975		1976		1977		1978		1979		1980	
Arab Countries	328.9	49.6	335.7	49.6	342.2	51.9	338.0	53.1	340.5	52.7	346.7	54.0	341.1	53.2
Algeria	7.6	1.1	7.7	1.1	7.4	1.1	6.8	1.1	6.6	1.0	6.3	1.0	8.4	1.3
Bahrain	0.4	0.1	0.4	0.1	0.3	0.1	0.3	0.1	0.3	–	0.3	–	0.2	–
Egypt	5.1	0.8	3.7	0.6	3.9	0.6	1.9	0.3	2.4	0.4	3.2	0.5	3.1	0.5
Iraq	31.5	4.7	35.0	5.2	34.3	5.2	34.0	5.3	34.5	5.3	32.1	5.0	31.0	4.8
Kuwait	72.8	11.0	72.8	10.7	71.2	10.8	70.5	11.1	70.1	10.9	69.4	10.8	68.5	10.7
Libyan Arab Jamahiriya	25.5	3.8	26.6	3.9	26.1	3.9	25.5	4.0	25.0	3.9	24.3	3.8	23.5	3.7
Morocco	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oman	5.2	0.8	6.0	0.9	5.9	0.9	5.8	0.9	5.6	0.9	2.5	0.4	2.4	0.4
Qatar	6.5	1.0	6.0	0.9	5.9	0.9	5.7	0.9	5.6	0.9	4.0	0.6	3.8	0.6
Saudi Arabia	140.7	21.2	141.0	20.8	151.8	23.0	151.4	23.8	153.1	23.7	168.9	26.3	166.5	25.9
Syrian Arab Republic	7.1	1.1	1.5	0.2	2.2	0.3	2.2	0.3	2.2	0.3	2.1	0.3	2.0	0.3
Tunisia	1.0	0.2	1.1	0.2	1.0	0.2	2.7	0.4	2.7	0.4	2.3	0.4	2.3	0.4
United Arab Emirates	25.5	3.8	33.9	5.0	32.2	4.9	31.2	4.9	32.4	5.0	31.3	4.9	29.4	4.6
(Abu Dhabi)	(21.5)	(3.2)	(30.0)	(4.4)	(29.5)	(4.5)	(29.0)	(4.6)	(31.0)	(4.8)	(30.0)	(4.7)	(28.0)	(4.4)
(Dubai)	(2.5)	(0.4)	(2.4)	(0.4)	(1.4)	(0.2)	(1.5)	(0.2)	(1.4)	(0.2)	(1.3)	(0.2)	(1.4)	(0.2)
(Sharjah)	(1.5)	(0.2)	(1.5)	(0.2)	(1.3)	(0.2)	(0.7)	(0.1)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	104.5	15.8	116.9	17.2	116.4	17.7	108.3	17.0	108.9	16.9	105.4	16.4	102.9	16.0
Iran	60.0	9.1	66.0	9.7	64.5	9.8	63.0	9.9	62.0	9.6	59.0	9.2	58.0	9.0
Nigeria	20.0	3.0	20.9	3.1	20.2	3.1	19.5	3.1	18.7	2.9	18.2	2.8	17.4	2.7
Venezuela	14.0	2.1	15.0	2.2	17.7	2.7	15.3	2.4	18.2	2.8	18.0	2.8	17.9	2.8
Indonesia	10.5	1.6	15.0	2.2	14.0	2.1	10.5	1.6	10.0	1.6	10.2	1.6	9.6	1.5
OECD Countries	61.5	9.3	72.3	10.7	66.8	10.2	63.3	9.9	64.2	9.9	60.8	9.5	58.9	9.2
USA	35.3	5.3	35.3	5.2	32.7	5.0	30.9	4.8	29.5	4.6	28.5	4.5	26.5	4.1
Canada	7.7	1.2	9.4	1.4	7.1	1.1	6.2	1.0	6.0	0.9	6.0	0.9	6.8	1.1
Japan	–	–	–	–	–	–	–	–	0.1	–	0.1	–	0.1	–
EEC	11.4	1.7	17.4	2.6	17.9	2.7	18.4	2.9	20.0	3.1	17.4	2.7	17.0	2.7
(United Kingdom)	(10.0)	(1.5)	(15.7)	(2.3)	(16.0)	(2.4)	(16.8)	(2.6)	(19.0)	(3.0)	(16.0)	(2.5)	(15.4)	(2.4)
(Others)	(1.4)	(0.2)	(1.7)	(0.3)	(1.9)	(0.3)	(1.6)	(0.3)	(1.0)	(0.1)	(1.4)	(0.2)	(1.6)	(0.3)
Other OECD Europe	4.6	0.7	8.3	1.2	7.3	1.1	6.2	1.0	6.5	1.0	6.6	1.0	6.3	1.0
OECD Oceania	2.5	0.4	2.4	0.3	1.8	0.3	1.6	0.2	2.1	0.3	2.2	0.4	2.2	0.3
Mexico	3.6	0.5	13.6	2.0	9.5	1.4	7.0	1.1	14.0	2.2	16.0	2.5	31.2	4.9
USSR	80.0	12.1	83.4	12.3	80.4	12.2	78.1	12.3	75.0	11.6	71.0	11.1	67.0	10.4
China	20.0	3.0	25.0	3.7	20.0	3.0	20.0	3.1	20.0	3.1	20.0	3.1	20.0	3.1
Other Countries	64.2	9.7	31.1	4.5	23.4	3.6	22.1	3.5	23.2	3.6	21.7	3.4	20.5	3.2
World Total	662.7	100.0	678.0	100.0	658.7	100.0	636.8	100.0	645.8	100.0	641.6	100.0	641.6	100.0

Table A3.2

World Crude Production Since Commencement (Mb, percentage).*

	Cumulative Through 1953		1954		1955		1956		1957		1958		1959	
Arab Countries	4,048.7	5.2	993.9	19.7	1,073.2	19.1	1,076.1	17.5	1,047.6	16.2	1,281.9	19.2	1,369.5	19.2
Algeria	1.1	–	0.6	–	0.4	–	0.3	–	0.2	–	3.2	–	9.4	0.1
Bahrain	153.9	0.2	11.0	0.2	11.0	0.2	11.0	0.2	11.7	0.2	14.9	0.2	16.5	0.2
Egypt	202.1	0.3	16.3	0.3	13.0	0.2	12.4	0.2	17.2	0.3	22.8	0.3	22.6	0.3
Iraq	917.6	1.2	227.4	4.5	246.8	4.4	233.7	3.8	163.4	2.5	266.0	4.0	311.4	4.4
Kuwait	1,077.2	1.4	350.3	7.0	402.8	7.2	405.7	6.6	427.6	6.6	524.1	7.9	526.0	7.4
Libyan Arab Jamahiriya	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Morocco	2.9	–	0.8	–	0.7	–	0.6	–	0.6	–	0.7	–	0.7	–
Oman	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Qatar	87.3	0.1	36.5	0.7	42.0	0.7	45.4	0.7	50.6	0.8	63.9	1.0	62.2	0.9
Saudi Arabia	1,606.6	2.0	351.0	7.0	356.5	6.3	367.0	6.0	376.3	5.8	386.3	5.8	420.7	5.9
Syrian Arab Republic	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunisia	–	–	–	–	–	–	–	–	–	–	–	–	–	–
United Arab Emirates	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Abu Dhabi)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	11,460.6	14.4	793.6	15.8	993.4	17.6	1,190.8	19.4	1,391.0	21.6	1,372.9	20.8	1,490.5	20.9
Iran	2,533.1	3.2	22.4	0.4	120.0	2.1	198.3	3.2	262.7	4.1	301.5	4.6	338.8	4.7
Nigeria	–	–	–	–	–	–	–	–	–	–	1.9	–	4.1	0.1
Venezuela	7,468.9	9.4	691.8	13.8	787.4	14.0	899.2	14.7	1,014.4	15.7	950.8	14.4	1,011.4	14.2
Indonesia	1,458.6	1.8	79.4	1.6	86.0	1.5	93.3	1.5	113.9	1.8	118.7	1.8	136.2	1.9
OECD Countries	48,553.4	61.3	2,471.3	49.0	2,684.8	47.7	2,868.0	46.8	2,888.6	44.6	2,708.2	40.9	2,859.8	40.0
USA	47,884.1	60.5	2,315.0	46.0	2,484.6	44.1	2,617.3	42.7	2,616.9	40.5	2,449.0	37.0	2,574.6	36.0
Canada	337.2	0.4	96.1	1.9	129.4	2.3	172.0	2.8	181.9	2.8	165.5	2.5	184.8	2.6
Japan	93.0	0.1	2.2	–	2.3	–	2.3	–	2.4	–	2.7	–	3.0	–
EEC	199.1	0.3	31.8	0.6	39.5	0.7	48.1	0.8	60.8	0.9	66.7	1.0	75.6	1.1
(United Kingdom)	(5.9)	(–)	(1.2)	(–)	(1.1)	(–)	(1.1)	(–)	(1.1)	(–)	(1.1)	(–)	(1.1)	(–)
(Others)	(193.2)	(0.3)	(30.6)	(0.6)	(38.4)	(0.7)	(47.0)	(0.8)	(59.7)	(0.9)	(65.6)	(1.0)	(74.5)	(1.1)
Other OECD Europe	–	–	26.2	0.5	29.0	0.5	28.3	0.5	26.6	0.4	24.3	0.4	21.8	0.3
OECD Oceania	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mexico	2,744.9	3.5	83.7	1.7	89.4	1.6	90.7	1.5	88.3	1.4	93.5	1.4	96.4	1.3
USSR	9,429.7	11.9	435.6	8.7	520.4	9.2	615.8	10.0	722.6	11.2	831.9	12.6	952.0	13.3
China	32.8	0.1	5.8	0.1	7.1	0.1	8.5	0.1	10.7	0.2	16.6	0.3	27.1	0.4
Other Countries	2,881.3	3.6	244.4	5.0	264.5	4.7	279.8	4.7	310.9	4.8	316.3	4.7	350.0	4.9
World Total	79,151.4	100.0	5,028.3	100.0	5,632.8	100.0	6,129.7	100.0	6,459.7	100.0	6,621.3	100.0	7,145.3	100.0

*For each year, the figures are in million barrels under the first column and a percentage of the total under the second column.

Note:

A dash (–) indicates nil or negligible.

Sources: Oil and Gas Journal (Annual Worldwide Report issues and the issue of 25 February 1980), OPEC *Annual Statistical Bulletin* issues, United Nations *World Energy Supplies* (Statistical Papers, Series J), and *Energy Policies of the World,* edited by G.J. Mangone, American Elsevier Publishing Company (Volume I).

Table A3.2 (continued)

World Crude Production Since Commencement (Mb, percentage).*

	1960		1961		1962		1963		1964		1965		1966	
Arab Countries	1,623.5	21.0	1,773.0	21.6	2,030.0	22.8	2,328.6	24.3	2,725.1	26.4	3,049.9	27.6	3,583.0	29.9
Algeria	66.3	0.9	120.8	1.5	159.5	1.8	184.1	1.9	204.1	2.0	203.9	1.8	362.3	3.0
Bahrain	16.5	0.2	16.4	0.2	16.4	0.2	16.5	0.2	18.0	0.2	20.8	0.2	22.5	0.2
Egypt	23.8	0.3	27.3	0.3	33.9	0.4	40.4	0.4	45.5	0.1	46.4	0.4	44.8	0.4
Iraq	352.5	4.6	363.7	4.4	365.1	4.1	420.8	4.4	457.6	4.4	478.8	4.3	504.7	4.2
Kuwait	619.2	8.0	632.3	7.7	714.6	8.0	765.2	8.0	842.2	8.2	861.5	7.8	906.7	7.6
Libyan Arab Jamahiriya	–	–	6.6	0.1	66.5	0.7	161.3	1.7	315.6	3.1	444.9	4.0	547.9	4.6
Morocco	0.6	–	1.0	–	1.1	–	0.9	–	0.8	–	0.8	–	0.8	–
Oman	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Qatar	63.9	0.8	64.7	0.8	68.0	0.8	69.9	0.7	78.8	0.8	84.9	0.8	106.3	0.9
Saudi Arabia	480.7	6.2	540.2	6.6	599.7	6.7	651.9	6.8	694.1	6.7	804.9	7.3	949.7	7.9
Syrian Arab Republic	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunisia	–	–	–	–	–	–	–	–	–	–	–	–	5.9	–
United Arab Emirates	–	–	–	–	5.2	0.1	17.6	0.2	68.4	0.7	103.0	0.9	131.4	1.1
(Abu Dhabi)	(–)	(–)	(–)	(–)	(5.2)	(0.1)	(17.6)	(0.2)	(68.4)	(0.7)	(103.0)	(0.9)	(131.4)	(1.1)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	1,588.8	20.6	1,676.3	20.5	1,845.1	20.8	1,919.8	20.1	2,079.0	20.2	2,238.6	20.3	2,330.6	19.5
Iran	390.8	5.1	438.8	5.4	487.1	5.5	544.3	5.7	626.1	6.1	695.5	6.3	778.1	6.5
Nigeria	6.4	0.1	16.8	0.2	24.6	0.3	27.9	0.3	44.0	0.4	100.1	0.9	152.4	1.3
Venezuela	1,041.7	13.5	1,065.8	13.0	1,167.9	13.1	1,185.5	12.4	1,241.8	12.1	1,267.6	11.5	1,230.5	10.3
Indonesia	149.9	1.9	154.9	1.9	165.5	1.9	162.1	1.7	167.1	1.6	175.4	1.6	169.6	1.4
OECD Countries	2,874.8	37.5	2,960.8	36.2	3,045.9	34.3	3,144.3	33.1	3,208.8	31.2	3,298.7	29.6	3,502.1	29.2
USA	2,574.9	33.5	2,621.8	32.0	2,676.2	30.1	2,752.7	28.9	2,786.8	27.1	2,848.5	25.6	3,027.7	25.3
Canada	189.7	2.5	221.0	2.7	244.3	2.7	257.7	2.7	274.6	2.7	296.4	2.7	320.5	2.7
Japan	3.9	0.1	4.8	0.1	5.7	0.1	5.9	0.1	5.0	–	4.9	–	5.7	–
EEC	84.6	1.1	91.7	1.1	96.8	1.1	102.6	1.1	114.0	1.1	113.9	1.0	109.7	0.9
(United Kingdom)	(1.1)	(–)	(1.1)	(–)	(1.0)	(–)	(0.9)	(–)	(1.0)	(–)	(0.7)	(–)	(0.6)	(–)
(Others)	(83.5)	(1.1)	(90.6)	(1.1)	(95.8)	(1.1)	(101.7)	(1.1)	(113.0)	(1.1)	(113.2)	(1.0)	(109.1)	(0.9)
Other OECD Europe	21.7	0.3	21.5	0.3	22.9	0.3	25.4	0.3	27.0	0.3	32.5	0.3	35.3	0.3
OECD Oceania	–	–	–	–	–	–	–	–	1.4	–	2.5	–	3.2	–
Mexico	99.1	1.3	106.8	1.3	111.8	1.3	114.9	1.2	115.6	1.1	118.0	1.1	121.2	1.0
USSR	1,086.5	14.1	1,220.3	14.9	1,368.5	15.4	1,514.2	15.9	1,643.0	16.0	1,784.7	16.2	1,948.1	16.3
China	40.2	0.5	45.4	0.6	49.7	0.6	54.9	0.6	62.2	0.6	73.1	0.7	95.1	0.8
Other Countries	381.7	5.0	408.1	4.9	439.1	4.8	460.9	4.8	461.9	4.5	477.1	4.5	407.0	3.3
World Total	7,694.6	100.0	8,190.7	100.0	8,890.1	100.0	9,537.6	100.0	10,295.6	100.0	11,040.1	100.0	11,987.1	100.0

Table A3.2 (continued)

World Crude Production Since Commencement (Mb, percentage)*.

	1967		1968		1969		1970		1971		1972		1973	
Arab Countries	3,679.4	28.6	4,416.8	31.5	4,863.3	32.2	5,375.0	32.5	5,673.9	32.2	6,041.3	32.5	6,834.4	33.5
Algeria	301.4	2.3	331.0	2.4	345.4	2.3	375.6	2.3	286.7	1.6	388.8	2.1	400.5	2.0
Bahrain	25.4	0.2	27.6	0.2	27.8	0.2	28.0	0.2	27.3	0.2	25.5	0.1	24.9	0.1
Egypt	39.9	0.3	61.4	0.4	88.0	0.6	117.4	0.7	107.0	0.6	76.7	0.4	60.9	0.3
Iraq	444.7	3.5	547.9	3.9	555.2	3.7	565.2	3.4	618.3	3.5	536.4	2.9	736.6	3.6
Kuwait	912.4	7.1	956.6	6.8	1,012.3	6.7	1,091.2	6.6	1,166.8	6.6	1,201.6	6.5	1,102.5	5.4
Libyan Arab Jamahiriya	635.3	4.9	952.4	6.8	1,134.8	7.5	1,211.1	7.3	1,007.7	5.7	819.6	4.4	793.9	3.9
Morocco	0.8	–	0.7	–	0.4	–	0.4	–	0.2	–	0.2	–	0.3	–
Oman	20.9	0.2	87.8	0.6	119.7	0.8	121.3	0.7	107.4	0.6	102.8	0.6	106.9	0.5
Qatar	118.1	0.9	124.3	0.9	129.8	0.9	132.3	0.8	157.2	0.9	176.5	0.9	208.2	1.0
Saudi Arabia	1,023.8	8.0	1,113.7	7.9	1,173.9	7.8	1,386.7	8.4	1,740.6	9.9	2,202.0	11.8	2,772.6	13.6
Syrian Arab Republic	–	–	7.1	0.1	18.1	0.1	29.3	0.2	36.6	0.2	40.5	0.2	38.3	0.2
Tunisia	17.2	0.1	24.5	0.2	28.4	0.2	31.9	0.2	31.4	0.2	30.5	0.2	29.4	0.1
United Arab Emirates	139.5	1.1	181.8	1.3	229.5	1.5	284.6	1.7	386.7	2.2	440.2	2.4	559.4	2.8
(Abu Dhabi)	(139.5)	(1.1)	(181.8)	(1.3)	(229.5)	(1.5)	(272.1)	(1.6)	(355.4)	(2.0)	(394.5)	(2.1)	(503.6)	(2.5)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(12.5)	(0.1)	(31.3)	(0.2)	(45.7)	(0.3)	(55.8)	(0.3)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	2,544.1	19.8	2,630.1	18.8	3,012.1	19.9	3,457.9	20.9	3,836.6	21.7	4,077.2	21.9	4,606.2	22.6
Iran	950.2	7.4	1,039.4	7.4	1,232.2	8.1	1,397.6	8.4	1,656.9	9.4	1,838.5	9.9	2,139.2	10.5
Nigeria	116.5	0.9	51.4	0.4	197.2	1.3	395.3	2.4	558.9	3.2	664.6	3.6	749.8	3.7
Venezuela	1,292.9	10.0	1,319.4	9.4	1,311.8	8.7	1,353.4	8.2	1,295.4	7.3	1,178.5	6.3	1,228.6	6.0
Indonesia	184.5	1.4	219.9	1.6	270.9	1.8	311.6	1.9	325.4	1.8	395.6	2.1	488.6	2.4
OECD Countries	3,727.8	29.0	3,875.9	27.5	3,950.8	26.1	4,185.6	25.3	4,203.2	23.9	4,281.0	23.0	4,302.4	21.2
USA	3,215.7	25.0	3,329.0	23.7	3,371.4	22.3	3,517.0	21.2	3,453.5	19.6	3,455.4	18.5	3,360.9	16.5
Canada	351.3	2.7	379.4	2.7	409.8	2.7	460.0	2.8	491.2	2.8	560.7	3.0	654.5	3.2
Japan	5.8	–	5.4	–	5.5	–	5.6	–	5.5	–	5.3	–	5.1	–
EEC	107.7	0.8	105.6	0.7	102.1	0.7	96.9	0.6	90.5	0.5	84.1	0.5	77.4	0.4
(United Kingdom)	(0.6)	(–)	(0.6)	(–)	(0.6)	(–)	(0.6)	(–)	(0.6)	(–)	(0.6)	(–)	(0.6)	(–)
(Others)	(107.1)	(0.8)	(104.8)	(0.7)	(101.5)	(0.7)	(96.3)	(0.6)	(89.9)	(0.5)	(83.5)	(0.5)	(76.8)	(0.4)
Other OECD Europe	39.7	0.3	42.8	0.3	47.1	0.3	46.8	0.3	45.9	0.3	54.9	0.3	60.9	0.3
OECD Oceania	7.6	0.1	13.9	0.1	14.9	0.1	59.3	0.4	116.6	0.7	120.6	0.6	143.6	0.7
Mexico	133.4	1.0	142.3	1.0	150.2	1.0	153.3	0.9	152.7	0.9	158.1	0.8	165.9	0.8
USSR	2,116.7	16.4	2,271.6	16.2	2,412.9	15.9	2,594.1	15.6	2,770.7	15.7	2,942.4	15.8	3,152.5	15.5
China	80.5	0.6	109.8	0.8	102.4	0.7	146.3	0.9	268.1	1.5	314.1	1.7	374.8	1.8
Other Countries	592.3	4.6	612.0	4.2	640.5	4.2	691.1	3.9	741.0	4.1	811.9	4.3	892.2	4.6
World Total	12,874.2	100.0	14,058.5	100.0	15,132.5	100.0	16,603.3	100.0	17,646.2	100.0	18,626.0	100.0	20,328.4	100.0

*For each year, the figures are in million barrels under the first column and a percentage of the total under the second column.

Note:

A dash (–) indicates nil or negligible.

Sources: Oil and Gas Journal (Annual Worldwide Report issues and the issue of 25 February 1980), OPEC *Annual Statistical Bulletin* issues, United Nations *World Energy Supplies* (Statistical Papers, Series J), and *Energy Policies of the World,* edited by G.J. Mangone, American Elsevier Publishing Company (Volume I).

	1974		1975		1976		1977		1978		1979		Cumulative Through 1979	
Arab Countries	6,729.1	32.9	6,166.9	31.9	7,172.4	34.3	7,411.2	33.8	7,178.1	32.5	8,057.0	35.2	107,602.8	25.2
Algeria	368.1	1.8	358.7	1.9	393.5	1.9	420.9	1.9	447.1	2.0	405.9	1.8	6,139.8	1.4
Bahrain	24.6	0.1	22.3	0.1	21.2	0.1	19.7	0.1	19.3	0.1	18.2	0.1	668.9	0.2
Egypt	53.3	0.3	84.0	0.4	119.9	0.6	148.9	0.7	176.7	0.8	184.7	0.8	1,887.3	0.5
Iraq	719.3	3.5	825.5	4.3	884.0	4.2	857.1	3.9	959.6	4.3	1,253.4	5.5	14,812.7	3.5
Kuwait	929.3	4.5	760.7	3.9	785.2	3.8	718.7	3.3	765.8	3.5	909.8	4.0	21,368.3	5.0
Libyan Arab Jamahiriya	555.3	2.7	540.1	2.8	707.3	3.4	753.1	3.4	723.4	3.3	750.4	3.3	12,127.2	2.8
Morocco	0.2	–	0.1	–	0.1	–	0.4	–	0.4	–	0.4	–	17.6	–
Oman	105.8	0.5	124.4	0.6	133.6	0.6	127.7	0.6	115.0	0.5	107.7	0.5	1,381.0	0.3
Qatar	189.2	0.9	159.7	0.8	182.0	0.9	162.3	0.7	177.0	0.8	182.1	0.8	3,023.1	0.7
Saudi Arabia	3,095.1	15.1	2,582.5	13.3	3,139.3	15.0	3,367.0	15.4	3,026.6	13.7	3,480.1	15.2	38,689.5	9.1
Syrian Arab Republic	44.4	0.2	66.2	0.3	69.1	0.3	73.0	0.3	62.1	0.3	59.5	0.2	544.2	0.1
Tunisia	31.8	0.2	35.4	0.2	28.5	0.1	32.9	0.2	36.5	0.2	36.5	0.1	400.8	0.1
United Arab Emirates	612.7	3.0	607.3	3.1	708.7	3.4	729.5	3.3	668.6	3.0	668.3	2.9	6,542.4	1.5
(Abu Dhabi)	(512.8)	(2.5)	(500.6)	(2.5)	(580.7)	(2.8)	(602.9)	(2.7)	(528.5)	(2.4)	(534.4)	(2.3)	(5,661.9)	(1.3)
(Dubai)	(80.2)	(0.4)	(92.8)	(0.5)	(114.5)	(0.5)	(116.4)	(0.5)	(132.1)	(0.6)	(129.2)	(0.6)	(810.5)	(0.2)
(Sharjah)	(19.7)	(0.1)	(13.9)	(0.1)	(13.5)	(0.1)	(10.2)	(0.1)	(8.0)	(–)	(4.7)	(–)	(70.0)	(–)
Other Major OPEC Countries	4,609.1	22.6	3,937.0	20.4	4,299.6	20.5	4,260.2	19.4	4,005.6	18.1	3,420.8	15.0	81,067.7	19.0
Iran	2,197.9	10.8	1,952.8	10.1	2,153.1	10.3	2,066.9	9.4	1,921.4	8.7	1,134.8	5.0	29,418.6	6.9
Nigeria	823.1	4.0	650.9	3.4	756.5	3.6	761.1	3.5	697.2	3.1	843.9	3.7	7,644.6	1.8
Venezuela	1,086.4	5.3	856.4	4.4	839.7	4.0	816.8	3.7	789.5	3.6	859.9	3.8	35,253.4	8.3
Indonesia	501.7	2.5	476.9	2.5	550.3	2.6	615.4	2.8	597.5	2.7	582.2	2.5	8,751.1	2.0
OECD Countries	4,102.7	20.1	3,930.4	20.3	3,908.5	18.6	4,117.2	18.7	4,443.2	20.1	4,671.6	20.4	140,729.8	33.0
USA	3,202.6	15.7	3,056.8	15.8	2,968.9	14.2	2,985.3	13.6	3,175.9	14.4	3,137.5	13.7	124,460.0	29.2
Canada	613.6	3.0	521.1	2.7	479.8	2.3	482.2	2.2	479.2	2.2	546.0	2.4	9,499.9	2.2
Japan	4.9	–	4.4	–	4.2	–	3.7	–	3.7	–	2.9	–	205.8	–
EEC	72.8	0.4	77.7	0.4	152.7	0.7	347.5	1.6	459.2	2.1	638.4	2.8	3,647.3	0.9
(United Kingdom)	(0.6)	(–)	(8.9)	(0.1)	(85.1)	(0.4)	(280.3)	(1.3)	(394.9)	(1.8)	(572.3)	(2.5)	(1,365.3)	(0.3)
(Others)	(72.2)	(0.4)	(68.8)	(0.3)	(67.6)	(0.3)	(67.2)	(0.3)	(64.3)	(0.3)	(66.1)	(0.3)	(2,282.0)	(0.6)
Other OECD Europe	66.6	0.3	119.4	0.6	146.5	0.7	141.2	0.6	167.5	0.7	185.8	0.8	1,507.6	0.4
OECD Oceania	142.2	0.7	151.0	0.8	156.4	0.7	157.3	0.7	157.7	0.7	161.0	0.7	1,409.2	0.3
Mexico	211.0	1.0	260.0	1.3	294.8	1.4	358.1	1.6	440.6	2.0	533.3	2.3	7,223.0	1.7
USSR	3,372.3	16.5	3,606.4	18.6	3,818.5	18.2	3,985.8	18.2	4,171.2	18.9	4,271.6	18.6	65,560.0	15.4
China	475.4	2.3	548.5	2.8	621.7	3.0	652.6	3.0	759.2	3.4	786.6	3.4	5,769.2	1.4
Other Countries	930.2	4.6	909.0	4.7	820.4	4.0	1,162.4	5.3	1,104.7	5.0	1,169.1	5.1	18,804.9	4.3
World Total	20,429.8	100.0	19,358.2	100.0	20,935.9	100.0	21,947.5	100.0	22,102.6	100.0	22,910.0	100.0	426,757.4	100.0

Table A3.3

World Reserves to Production (R/P) Ratio, 1954-1979.*

	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Arab Countries	64	77	93	109	107	106	94	88	78	72	68	63	54
Algeria	8	13	17	75	126	372	75	43	35	35	34	37	20
Bahrain	27	18	18	17	13	12	12	12	12	12	11	10	9
Egypt	6	8	16	17	13	18	21	22	21	17	33	32	45
Iraq	57	58	86	135	94	80	71	74	73	62	56	52	50
Kuwait	58	75	99	118	119	120	106	103	93	87	81	80	76
Libyan Arab Jamahiriya	–	–	–	–	–	100	1,500	303	45	28	22	20	18
Morocco	5	21	23	17	13	12	14	10	9	17	19	19	18
Oman	–	–	–	–	–	–	–	–	–	–	–	500	500
Qatar	41	36	33	30	28	40	39	39	41	43	38	41	28
Saudi Arabia	80	102	101	107	122	119	111	98	92	86	94	83	70
Syrian Arab Republic	–	–	–	–	–	–	–	100	100	100	300	500	1,200
Tunisia	–	–	–	–	–	–	–	–	–	–	–	–	51
United Arab Emirates	–	–	–	–	–	–	–	–	–	284	110	75	76
(Abu Dhabi)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(284)	(110)	(75)	(76)
(Dubai)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Other Major OPEC Countries	35	28	35	35	40	39	39	38	34	34	31	30	30
Iran	670	125	136	114	106	97	90	81	72	68	59	55	51
Nigeria	–	–	–	–	5	6	13	6	12	14	11	10	20
Venezuela	16	15	15	13	17	16	17	17	15	14	14	13	14
Indonesia	32	22	25	44	63	62	60	61	57	62	60	57	56
OECD Countries	13	12	12	13	14	14	14	14	14	13	13	12	12
USA	13	12	12	13	14	13	13	13	13	13	12	11	10
Canada	21	17	16	19	24	22	24	23	21	18	21	21	21
Japan	13	23	10	9	9	17	26	21	18	17	20	10	8
EEC	13	18	60	15	14	15	14	14	13	13	12	13	15
(United Kingdom)	(3)	(4)	(5)	(5)	(6)	(6)	(6)	(5)	(6)	(7)	(1)	(1)	(17)
(Others)	(13)	(18)	(19)	(15)	(14)	(15)	(14)	(14)	(14)	(13)	(12)	(13)	(15)
Other OECD Europe	4	4	18	15	17	18	14	14	13	12	22	31	23
OECD Oceania	–	–	–	–	–	–	–	–	–	100	71	40	31
Mexico	20	20	21	28	29	26	25	22	22	22	22	24	21
USSR	21	18	16	33	30	27	26	26	24	19	17	16	16
China	4	4	3	65	48	19	22	18	10	6	5	4	3
Other Countries	11	13	2	11	16	16	18	18	25	17	17	18	21
World Total	27	28	31	36	40	39	38	37	35	33	32	31	29

*Ratio of reserves at beginning of year to production of that year.

Sources: Tables A3.1 and A3.2.

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Arab Countries	60	55	53	61	60	75	55	49	54	48	46	48	43
Algeria	24	21	20	21	105	32	117	21	22	19	16	16	14
Bahrain	8	7	8	11	22	24	16	16	18	14	15	16	14
Egypt	23	23	24	43	42	52	86	96	44	33	13	14	18
Iraq	54	43	50	48	52	67	39	44	42	39	40	37	26
Kuwait	82	80	76	68	69	65	66	78	96	91	98	90	76
Libyan Arab Jamahiriya	32	31	26	29	29	31	38	46	49	37	34	35	32
Morocco	16	17	20	19	5	6	3	4	2	1	1	1	1
Oman	24	29	21	41	16	51	47	49	48	44	45	49	24
Qatar	34	30	30	42	27	34	34	34	38	32	35	32	23
Saudi Arabia	71	73	72	106	81	72	53	46	55	48	46	51	49
Syrian Arab Republic	1,500	211	83	51	41	180	188	160	23	32	30	35	35
Tunisia	17	16	18	16	16	20	34	32	31	35	82	74	60
United Arab Emirates	90	83	83	60	33	47	41	42	56	45	43	49	47
(Abu Dhabi)	(90)	(83)	(78)	(59)	(33)	(48)	(41)	(59)	(59)	(51)	(48)	(59)	(57)
(Dubai)	(–)	(–)	(1,000)	(80)	(32)	(35)	(36)	(31)	(26)	(12)	(13)	(11)	(10)
(Sharjah)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(76)	(108)	(96)	(69)	(2)	(3)
Other Major OPEC Countries	29	28	27	24	27	22	23	23	30	27	25	27	31
Iran	47	41	44	40	42	30	30	27	34	30	31	31	56
Nigeria	30	68	20	13	17	18	20	24	32	27	26	27	21
Venezuela	14	13	12	11	12	12	11	13	18	21	19	23	21
Indonesia	49	41	33	29	31	26	21	21	32	25	17	17	12
OECD Countries	11	11	11	10	13	15	13	15	18	17	15	15	13
USA	10	9	9	8	11	11	11	11	12	11	10	9	9
Canada	19	22	21	19	18	15	12	13	18	15	13	12	11
Japan	6	7	6	6	6	6	5	4	4	6	8	16	27
EEC	14	15	15	15	24	80	80	157	224	117	53	44	27
(United Kingdom)	(16)	(17)	(13)	(12)	(1,667)	(8,333)	(8,333)	(16,667)	(1,764)	(188)	(60)	(48)	(28)
(Others)	(14)	(15)	(15)	(15)	(13)	(20)	(16)	(19)	(25)	(28)	(24)	(15)	(21)
Other OECD Europe	30	23	19	17	39	142	44	69	70	50	44	39	36
OECD Oceania	79	29	168	42	19	26	17	18	17	12	10	13	13
Mexico	19	18	37	39	21	28	17	17	52	32	20	32	29
USSR	15	15	17	20	28	26	24	6	23	21	20	19	17
China	4	3	147	103	75	64	52	42	46	32	31	29	26
Other Countries	18	19	19	5	21	30	38	69	34	29	19	21	19
World Total	30	29	30	32	35	34	33	32	35	32	29	29	28

APPENDIX FOUR
BRIEF REMARKS ON OECD's "WORLD ENERGY OUTLOOK"

COMPARISON WITH OECD'S *"ENERGY PROSPECTS TO 1985"*

World Energy Outlook [5], released in January 1977, is both a revision and an extension of OECD's *Energy Prospects to 1985* [19], published two years before.

The revision is a dramatic one, and the new report is certainly more realistic than its predecessor, in terms of assumptions as well as projections. Among the major revisions to the earlier report, two are noteworthy for their policy implications. First, consumer oil demand in response to price changes is now projected to be much less elastic than it was assumed in 1974. Second, investment in energy conservation and production of alternative sources was assumed to respond almost immediately to higher oil prices, but this did not prove to be the case. Examples of differences between the two reports are 1) in the economic growth assumptions—the OECD area gross domestic product (GDP) in 1985 is estimated to be 12 percent below the earlier forecast—and 2) in the net oil import requirements per unit of GDP—the reference scenario of the new report projects these at 459 toe[1] per million dollars of GDP for 1985, as against 521 toe in 1976 (and during 1973-1976, on the average), while the scenario in the earlier report, which corresponds most closely to the (present) reference scenario, (see p. 31*)[2] had estimated them at 235 toe (almost half the revised forecast).

The extension is not as dramatic as the revision of the original report, although it may seem to be an important one, since the present report indicates (p. 8*) that it "encompasses the world, not simply the OECD as in the original study" and that it "looks at horizons beyond 1985." Actually, only 12 percent of the report is devoted to the world outside OECD. The energy prospects of OPEC countries, which are OECD's main oil suppliers, are studied in a little more than two pages. Projections to 1990 and 1995 are also treated in two and a half pages. Such simple space considerations are sufficient to give an indication about the limitations of the study's extension in geographical and time coverage beyond the OECD area and beyond 1985.

Another major conceptual difference between the two reports is that while the original assessment was primarily concerned with the effect of the OPEC price increases, the report under review attaches considerable importance to changes in economic growth. The earlier report considered scenarios based on three different oil price assumptions. The present assessment assumes that oil prices will remain constant in real terms, and bases its scenarios on three alternative economic growth variants. This revised approach reflects a fundamental shift in the attitude of the OECD toward future consumers/producers relations. When the first report was prepared in 1974 the reality of the then recent massive oil price rise was not taken for granted. Two years later the second assessment was

[1] Tons of oil equivalent (see Appendix 1, p. 103).

[2] In this appendix an asterisk (*) denotes a page number in the OECD report.

undertaken in a completely different atmosphere. The low rate of implementation of energy conservation measures in major countries, delays and downward revisions in nuclear programmes, and a slow progress in the development of other energy alternatives led OECD governments to realize that their plans to shift away from oil as the major fuel would take much more time than was originally anticipated. The idea of breaking OPEC prices through considerably reduced oil demand had, therefore, to be abandoned, in a new world context of major concern by the OECD about lower economic growth perspectives in the aftermath of the recession.

METHODOLOGY

Broadly speaking, the revised OECD projections are carried out within a methodological framework similar to the one adopted in the present study (see p. 26). However, the last two rows of the energy balance model ("Refineries" and "Gross final consumption") are excluded from the OECD model, while the second and third columns ("Crude petroleum" and "Petroleum products") are integrated in one (termed "Oil and NGL" in the OECD model). This integration clearly avoids the study of the refining sector–hence the exclusion of the "Refineries" row–which would have not only provided more refined forecasts but also shed some light on OECD's anticipations concerning this delicate producers/consumers issue.

Within the framework of the OECD five-row energy balance model, total energy requirements (TER) and total electricity generation (ELG) are projected, in the central reference scenario, mainly on the basis of most recently available government forecasts. The latter are adjusted, however, to suit the economic growth assumptions and energy conversion factors of the OECD secretariat. Future magnitudes of coal, oil, gas, and primary electricity output, as well as trade in coal, gas, and electricity, are estimated using government forecasts or, if not available, historical trends and/or secretariat assumptions. Official thermal electricity efficiency ratio forecasts and government estimates for coal and gas fueling thermoelectric plants are the basis for filling the electricity row of the energy balance model, except for oil input requirements, which are deduced by difference. Domestic oil requirements are also calculated by difference in the TER row. Finally, net oil imports emerge as the residual of the energy balance, and marine bunkers are estimated as a fixed proportion of oil imports.

To calculate future oil imports, by far the most important variable in the model, as a residual simply on the grounds that "to a large extent it mirrors the actual situation" (p. 30*) is not sufficiently convincing to counterbalance the two major shortcomings of this approach. First, it is clear that small errors in the projection of the other variables lead to large (additive) errors in the estimation of oil imports.[3] Second, the approach assumes that the oil exporting countries, essentially OPEC countries, would meet the desired oil imports of the OECD area, whatever their level (p. 13*). This is clearly indicated by the way the energy balances of OPEC countries are derived in the report, particularly their oil component (Table A22, p. 99*).

Concerning the alternative scenario to the central reference case that are examined in the OECD report, it is believed that their methodology raises some questions as to their effectiveness.

A central accelerated policy case is derived from the central reference scenario by adjusting energy consumption and production to savings and output increases that are expected to accrue from the implementation of vigorous conservation and domestic supply expansion policies. The policy proposals are described in detail in the report. However, the possible interactions between such policy changes and economic growth are not

[3] For example, a 5 percent error in the projection of each of the exogenously estimated relevant variables (TER, primary electricity generation, coal and gas production and imports, and oil domestic output) may result in net oil imports amounting to 44.2 Mb/d in 1985 for the OECD area in the central reference scenario, instead of the projected 35.0 Mb/d (Table 1, p. 9* and Table A1, p. 90*), i.e., an error of more than 26 percent.

investigated in the report, which, instead, maintains the level of GDP unchanged from the central reference scenario. In reality, policies designed to bring about a cut of over 30 percent in the net oil import needs of the OECD countries by 1985 (to be contributed 58 percent by supply expansion and 42 percent by conservation) are likely to have an effect on economic growth. In this connexion, however, the Executive Director of the IEA has communicated to ECWA "that the type of policies detailed do not inevitably interact with economic growth, at least not within the limitation of the model proposed to forecast energy demand."

A low and a high growth scenario are also derived from the central reference case by adjusting TER and ELG in direct proportion to the assumed downward or upward change in GDP. Consumption, production, and imports of energy other than oil are adjusted on the basis of judgements made by the OECD secretariat, and oil consumption, imports, and bunkers are again derived by the residual approach used in the central reference scenario. While the remarks made above on that residual approach still hold true here, it is not clear whether the TER and ELG estimates, "calculated by adjustments proportional to differences in 1985 GDP between these cases and the reference scenario" (p. 106*), are derived using 1) the same elasticities as in the reference case or 2) constant TER/GDP and ELG/GDP ratios.[4] The latter case, however, would imply an elasticity equal to 1 for both TER and ELG with respect to GDP, whereas the report indicates that the GDP elasticity of TER "for the period 1974 to 1985 is 0.84" (p. 27*). In this connexion, the Executive Director of the IEA has communicated to ECWA that "in both cases, TER were derived using the same TER/GDP elasticities as in the reference case." Anyway, such proportional adjustments go against the raison d'etre of these alternative growth scenarios, which are, according to the report, "constructed to show the sensitivity of oil import estimates to different assumed rates of economic growth" (p. 30*).

ECONOMIC GROWTH ASSUMPTIONS

The central scenario of the OECD report is based on assumed average annual growth rates in real GDP of 4.3 percent between 1974 and 1980 and 4.1 percent between 1980 and 1985 (p. 24*). However, recently published national accounts statistics and estimates of the OECD (-0.6, 5.1, 3.6, 3.9, 3.2, and 0.3 percent real GDP growth in 1975, 1976, 1977, 1978, 1979, and 1980, respectively [6, 20]) imply an economic performance for 1974–1980 (2.6 percent) much lower than the central scenario growth rate (4.3 percent). It would take an average annual growth rate of 6.2 percent between 1980 and 1985 (instead of 4.1 percent) to keep up with the OECD report's central scenario growth expectations, and such a high rate seems to be out of reach in the 1980s. Actually, even the low growth scenario of the OECD report (3.8 percent per year in 1974–1980 and 3.6 percent in 1980–1985) would now imply a 5.1 percent rate between 1980 and 1985, which is still quite high to be sustained over five years.

OECD/IEA's *Steam Coal: Prospects to 2000* [21], published two years after the present report (December 1978), recognizes the prospect of slower economic growth in the OECD area. Although this new report is not a study of overall energy forecasts, it provides a new set of basic assumptions as viewed in 1978. Real GDP is assumed to grow at 3.9 percent between 1976 and 1985. Bearing in mind the OECD statistics and estimates for 1977–1980 mentioned above, this means an average annual growth of 4.8 percent between 1980 and 1985, a rate even lower than the target implied in the low growth scenario of the present report for the same period but still too high to be sustained over five years.

OIL IMPORT PROJECTIONS

The central reference scenario projects net oil imports (including bunkers) of the OECD area in

[4] ECWA calculations based on each of these two methods have led to two sets of estimates that are both different (although by less than 1 percent) from the projections indicated in Tables A9 and A10 (pp. 94-95*).

1985 at 35 Mb/d. This estimate was adjusted upward by 2 Mb/d in the fall of 1977, mainly as a result of another slippage in nuclear schedules [22]. Yet, this scenario, as the Secretary General of the OECD puts it, "reflects a considerable effort in expanding supplies and reducing demand through conservation" [23]. The central accelerated policy scenario projects the potential reduction in oil import needs at 10.6 Mb/d, which, allowing for the 2 Mb/d upward adjustment of late 1977, would put net oil imports in 1985 at 26.4 Mb/d. In the low growth scenario net oil imports would be in the neighborhood of 34 Mb/d in 1985 (inclusive of the late 1977 upward adjustment).

Finally, the oil import limitations decided within the IEA in October 1977 and again in December 1979 are worthy of note. In October 1977 the IEA agreed to follow a course of action that would limit its (then 19) member countries' total net oil imports to 26 Mb/d by 1985 (excluding bunkers) [22]. This group target was revised downwards to 24.2 Mb/d in December 1979 [8]. Bearing in mind that the earlier objective did not include Australia, which joined the IEA in 1979, the reduction actually reaches 2.1 Mb/d.

The December 1979 IEA target for net oil imports in 1985, which established for the first time country-by-country ceilings as well, amounts to 25.8 Mb/d inclusive of bunkers. While Canada, Japan, Australia, and New Zealand are expected to do even better than in the central accelerated policy scenario, US oil import cuts would only represent 15 percent of the potential "savings" projected in that scenario, compared to 43 percent for the European members of the IEA. The share of the USA in total IEA net oil imports in 1985 is expected to exceed one-third, as against 30 percent in the central reference case, whereas Japan's share would be reduced from 28 percent in the reference case to 24 percent. The new IEA country ceilings, therefore, mainly underline the inability of the USA to effect energy conservation measures in the coming five years.

As of the writing of this book, the OECD/IEA had plans to publish in 1980 a *World Energy Outlook to 2000.*

APPENDIX FIVE
BRIEF REMARKS ON MIT / WAES's "ENERGY: GLOBAL PROSPECTS 1985-2000"

WAES

The Workshop on Alternative Energy Strategies (WAES), led by Carrol L. Wilson of the Massachusetts Institute of Technology (MIT), published in May 1977 its final report entitled *Energy: Global Prospects 1985–2000* [2]. This 300-page document is supported by three technical volumes of similar length: *Energy Demand Studies: Major-Consuming Countries, Energy Supply to the Year 2000: Global and National Studies,* and *Energy Supply Demand Integrations to the Year 2000: Global and National Studies.* The present review only relates to the main report.

WAES grouped about 75 "Participants" and "Associates" from 15 countries. Work started in October 1974. The national teams that *effectively* contributed to the project came from 11 OECD countries (which accounted in 1976 for more than 90 percent of the total OECD area gross domestic product) plus Mexico and Venezuela. It is noteworthy that the great majority of oil exporting countries did not participate in the project. The Arab world was completely left out,[1] despite the fact that Arab countries possess almost two-thirds of oil reserves in the world outside communist areas (WOCA) and WOCA oil is the main variable in the Workshop's projections. Since "an analysis of the future supply of oil is critical in any long-term energy study" (p. 111*),[2] it would have been desirable to undertake such an analysis in association with the countries that represent the main supply source. It is not surprising, therefore, that the assessments looked more carefully into the oil-importing industrialized countries, especially WAES countries, than into others.

The most important parts of the report, namely, Part I ("Global Energy Futures"), which is a detailed summary of the report and "the principle product of the Workshop Participants" (p. xxv*), and the "Oil" and "Natural Gas" chapters of Part II, were prepared by British Petroleum (BP) staff. The rest of the report was mainly written by MIT staff.

METHODOLOGY

Detailed assessments were carried out, by country or region, of future enegy (desired) demand and (potential) supply, using national and regional economic scenarios based on a set of global assumptions. A world supply-demand integration model is then applied to try to meet all end-use energy demands and achieve a balance between total energy supply and demand.

[1] Although Carrol Wilson indicated (p. x of the WAES report) that he "decided to select the 30 participants principally from the 15 industrialized countries that used 80 percent of the world's energy in 1972," which might imply a deliberate omission of the Arab world, he stated in a communication to ECWA that "it is unfortunate that Participants from the Arab world were not able to accept the numerous invitations extended to them to participate in the WAES study."

[2] In this appendix an asterisk (*) indicates a page number in the WAES report.

More precisely, the methodology involves the following steps:

1. Global assumptions.

(a) World economic growth: two assumptions (high or low).
(b) World price of oil (1985) or energy (2000): three assumptions (rising, constant, or falling) up to 1985 and two assumptions (rising or constant) after 1985.
(c) Gross additions to oil reserves: two assumptions (high or low).
(d) OPEC oil production ceiling: four assumptions (low, medium, high, or none).

2. National assumptions.

(a) Public energy policy response: two assumptions (vigorous or restrained) up to 1985 and one assumption (vigorous) after 1985.
(b) Principal replacement fuel (after 1985): two assumptions (coal or nuclear).
(c) Reserves to production (R/P) ratio lower limit: one assumption.

The above assumptions lead in theory to 96 possible scenarios for 1985 and to 64 possible scenarios in 2000. Out of these, five "useful" scenarios are selected to 1985, and the "most plausible" two are coupled to the 1985–2000 period.

3. National and regional economic scenarios are then constructed by the national teams on the basis of the assumptions in 1 and 2 above and modified in WAES meetings.

4. Assessment of national and regional energy (desired) demand and (potential) supply, on the basis of 1, 2, and 3 above, in the following way:

(a) Demand:
1977–1985:
(i) Divide the economy into 69 sectors.
(ii) Project economic activity by sector.
(iii) Project energy-use efficiency technical coefficients (elasticities?) by sector.
(iv) Estimate the 1985 desired energy demand using (ii) and (iii) above.

1985–2000:
(i) Condense the 69 sectors in (i) above into 17 sectors.
(ii) Use the 1977–1985 procedure.

(b) Supply:
1977–1985: Identify maximum potential supplies and the ways to develop them, on the basis of present output capacities and announced expansion projects.
1985–2000: Use the 1977–1985 procedure for coal and onshore oil, and special studies for other conventional fuels. For newer energy sources, (conservative) estimates are made on the basis of present technologies and costs.

5. Supply-demand integrations.

(a) Unconstrained integrations:
(i) Estimate gross final consumption (GFC), by end-use sector and by country-region.
(ii) Add energy transformation losses and energy sector's own use to GFC, to get total energy requirements (TER), which is equal to domestic potential supply plus desired imports (or minus potential exports).
(iii) Add up all countries/regions. If demand and supply for each fuel are in balance, geographical allocation is made on the basis of established patterns. If they are not, the differences for each fuel are noted.

(b) Constrained integrations:
Starting from the supply-demand differences for each fuel in the unconstrained approach, a highly constrained linear programming computer model is applied, with minimum and maximum constraints taking account of country/region preferred fuel mixes, where the objective function to

be minimized is the total cost to world consumers. Several thouand iterations may be needed in trying to meet all end-use energy demands and balance total supply and demand. Substantial fuel switching beyond preferred mixes may be necessary.

The methodology of the WAES report is more complete than many others, in the sense that it attempts to close the supply-demand gaps derived from the unconstrained integration of the national and regional assessments. The technique used (a constrained linear programming model), however, is not designed to close the gaps completely. The successive iterations lead to gradual switching from (preferred) fuels in relative shortage to other (not preferred) fuels in relative surplus. This switching operation stops when the total cost to world consumers (objective function) reaches its minimum level possible within specified maximum and minimum constraints. But gaps may remain, although much smaller than in the unconstrained approach. Actually, the results of the constrained integrations for 2000 show that, given all of the assumptions and conditions of the analysis, the prospective energy gap can be reduced by contributions from the potential coal surplus, small amounts of synthetic oil from coal, modest exports from communist areas, and processing losses saved by lowered electricity generation. A certain "unfulfilled demand" remains. Thus, none of the "plausible" scenarios discussed in the report could work out in reality, since energy supply-demand imbalances cannot occur in the real world.

The report, therefore, does not attempt to eliminate the fuel gaps completely. It would have been desirable, however, to present an "extension" or "revision" of at least one scenario where gaps are completely closed by forcing fuel shifts above the maxima or below the minima set by the constraints, and/or by revising global or national assumptions. Such a plausible "real" energy future would have been discussed in the report to show, for instance, how much more conservation would be needed, the (quantified) magnitude of the additional shift to coal, the extent to which economic growth should be reduced, etc., as well as the government actions required.

On the other hand, one may wonder whether the objective function selected in the linear programming model conforms with reality. The pattern calculated by the model is the one that yields least total costs to world consumers. In other terms, the model minimizes the inevitable losses of the energy content of each primary fuel in processing, refining, and conversion. Thus, fuel imbalances are reduced by allocating fuels so that, within maximum and minimum constraints, the energy content of each fuel is put to maximum use. This may (and actually would, as shown on page 259*) result, for example, in a less electrified future world society, since fossil-fueled electricity generation is the field where energy conversion losses are most important. Is it realistic that WOCA electricity output under the constrained (model) approach be cut down by 23 percent (about 5 trillion KWh) in 1985 and by one-third (over 12 trillion KWh) in 2000, as compared to the unconstrained (preferred mix) approach? Would a reduction by over 31 percent of preferred domestic uses of electricity be publicly acceptable in 1985? On the other hand, the constrained approach predicts that only primary electricity (nuclear, hydro, geothermal, etc.) would be produced in 2000, while the preferred mix allocates more than one-third of total generation to conventional thermal electricity. Is it possible that fossil-fueled stations, which are forecast to be responsible for 40 percent of WOCA power output in 1985 under the constrained approach, be completely abandoned 15 years later?

ECONOMIC GROWTH ASSUMPTIONS

The WAES projections are based on assumed average annual rates of economic growth for the world outside communist areas (WOCA) of 5.2 percent during 1977–1985 and 4.0 percent during 1985–2000 in the high growth case, and 3.4 percent and 2.8 percent, respectively, in the low growth case. These assumptions are translated into rates relevant to each country grouping as summarized in Table A5.1 (in average annual percentage).

Growth rate projections for North America, Western Europe, and Japan result from WAES national team estimates, based on WAES global

Table A5.1

WAES Economic Growth Assumptions, 1977-2000 (average annual percentage).

	High Growth		Low Growth	
	1977-1985	1985-2000	1977-1985	1985-2000
OECD	4.9	3.7	3.1	2.5
OPEC	7.2	6.5	5.5	4.3
Non-OPEC developing countries	6.2	4.6	4.2	3.7
Total WOCA	5.2	4.0	3.4	2.8

economic scenario assumptions. Rates for other groupings result from special studies, performed by the World Bank, based on WAES global economic scenario assumptions (p. 85*).

The average annual growth rate projected for the OECD area between 1977 and 1985 is 3.1 percent in the low growth case and 4.9 percent in the high growth case. This compares with 4.8 percent during 1960-1973. Recently published national accounts statistics and estimates of the OECD (3.9, 3.2, and 0.3 percent real GDP growth in 1978, 1979, and 1980, respectively [6, 20]), however, imply for the 1980-1985 period a growth rate of 3.5 percent in the low case and 6.4 percent in the high case. The latter rate seems to be out of reach for the OECD area as a whole in the 1980s. Even the low rate would call for very serious efforts to be sustained over five years.

OPEC countries' economic growth is (conservatively) estimated in the high growth case to return, in the 1977-1985 period, to levels comparable to its 1960-1972 performance (7.2 percent), down from its recent 12.5 percent per year growth between 1972 and 1976. Finally, non-OPEC developing countries' growth rates (derived from a World Bank study) are estimated to be roughly 1 percent greater than the OECD area rates throughout the period 1977-2000.

OIL IMPORT PROJECTIONS

Scenarios C-1 and D-8 are the major "plausible scenarios" presented in the WAES report. Scenario C-1 assumes: 1) high economic growth (see above), 2) a constant real oil price up to 1985, followed by a gradual energy price rise to reach 50 percent in real terms by 2000, 3) high (20 Bb per year) gross additions to WOCA oil reserves, 4) a ceiling of 45 Mb/d to OPEC oil production, 5) a vigorous national energy policy response throughout, 6) coal as the principal replacement fuel after 1985, 7) an R/P ratio limit of 15 to 1.

Scenario D-8 assumes: 1) low economic growth (see above), 2) a constant oil and energy price throughout, 3) low (10 Bb per year) gross additions to oil reserves, 4) a ceiling of 40 Mb/d to OPEC oil production, 5) a restrained (up to 1985) then vigorous national energy policy response, 6) nuclear energy as the principal replacement fuel after 1985, and 7) an R/P ratio limit of 15 to 1.

In both scenarios no energy supply-demand gap is foreseen for 1985. OPEC oil exports of about 36 Mb/d are expected to meet the import needs of the OECD (not more than 32 Mb/d in the two scenarios) and the non-OPEC developing countries (about 4 Mb/d). Both scenarios indicate 1989 as the year when WOCA oil supply ceases to meet demand. In 1990, it is projected that OPEC oil exports would fall 2-3 Mb/d short of WOCA import needs. The prospective oil shortage is then anticipated to widen significantly to reach 20 Mb/d in 2000 under scenario C-1 and 15 Mb/d under D-8.

It should be noted, however, that the different "plausible scenarios" presented in the WAES report appear to be quite sensitive to the "gross additions to oil reserves" variable, which represents one of the main global assumptions on which the projections are based. In fact, it is indicated in the report that "the assumptions made for gross additions to oil reserves may be considered by some observers to be conservative. Estimates that ultimately recoverable reserves may be 3,000 billion barrels or even higher have been published. If these estimates prove to be true, then gross addition to reserves may indeed be higher than our high case of 20 billion barrels per year. More optimistic estimates tend to be based on the assumption that either genuine new discoveries will be high in the future or that enhanced recovery will make a major contribution in the future.... Some estimates put the prospects for the developing countries much higher than we have. If oil exists in these areas and in the suggested volumes, then we might see a much higher level of genuine new discoveries than is assumed here" (pp. 142–144*).

In the particular case of scenarios C-1 and D-8, it is sufficient to raise the magnitudes assumed for gross additions to reserves by 10 Bb per year to overrule the conclusions reached in the report. Under C-1 if gross additions to reserves were raised from 20 to 30 Bb per year, which is slightly higher than the 27 Bb annual average witnessed in 1950–1975, and if (as a logical consequence) there were no constraints on OPEC oil production, such a rate of additions to reserves would allow production to meet potential demand in 2000. Demand could continue rising for the first five years of the next century, but some time before 2010 a limiting R/P ratio limit of 15 to 1 would be reached and production would peak and decline. If the R/P ratio limit was further lifted, this would ensure the oil supply-demand balance for another 20 to 30 years, depending on the level of gross additions to reserves after the year 2000. Under D-8, if gross additions to reserves were raised from 10 to 20 Bb per year, production could meet demand until 2004, unless the R/P ratio limit was lifted, in which case the supply-demand balance would extent to some time around 2025.

On the other hand, another scenario, which is not examined in detail in the report, also leads to matching supply and demand until after 2000. That scenario, D-3, combines the low growth and national policy response assumptions of D-8 with the five other assumptions of C-1 (pp. 66–67* and 262–264*). Under D-3 overall energy supply and demand would balance, there would be no prospective gaps in any fuel, and the peak in oil supply (due to the R/P ratio limit) would not occur until well after the turn of the century.

It is not clear why such "no gap" scenarios as those mentioned in the above two paragraphs (D-3, a variant to C-1 and a variant to D-8) are quickly disregarded in the report. It may not be enough to just state that "for a number of reasons, the plausibility of some such combinations could be in doubt" (p. 67*). The report would have gained in objectivity had one "no gap" scenario been presented in detail along with scenarios C-1 and D-8.

In the light of the above, one would be tempted to consider a more "optimistic" plausible conclusion to the report, based on one such "no gap" scenario. It might read: Oil supply is projected to continue to meet demand until after 2025, at a WOCA growth rate of between 3 and 4.5 percent per annum corresponding to a level of gross additions to oil reserves of between 20 and 30 Bb per year, respectively.

APPENDIX SIX
MATHEMATICAL FORMULATION AND APPLICATION OF TWO HYPOTHETICAL ARAB CRUDE PETROLEUM PRODUCTION POLICY MODELS

MODEL 1

Notation

- t: Subscript designating year t, $t \in \{0, 1, 2, \ldots\}$.
- R_t: Level of crude petroleum reserves at the beginning of year t, in billion barrels (Bb).
- A_t: Gross additions to crude petroleum reserves during year t, as a result of improved recovery, further development of existing fields, and new discoveries, in Bb.
- P_t: Crude petroleum production during year t, in Bb.
- a_t: Allowed reserves to production (R/P) ratio for year t.

For any t, $R_t \geqslant 0$, $P_t \geqslant 0$, and a_t is a positive integer.

Formulation

The relationship between reserves and production is by definition as follows:

$$(1)\quad R_t = a_t P_t \qquad t = 0, 1, \ldots$$

The relationship between the level of reserves in two consecutive years is as follows:

$$(2)\quad R_t = R_{t-1} + A_{t-1} - P_{t-1} \qquad t = 1, 2, \ldots$$

Formula (2) can be written as follows, using formula (1):

$$a_t P_t = a_{t-1} P_{t-1} + A_{t-1} - P_{t-1} \qquad t = 1, 2, \ldots$$

so that:

$$(3)\quad P_t = \frac{a_{t-1} - 1}{a_t} P_{t-1} + \frac{A_{t-1}}{a_t} \qquad t = 1, 2, \ldots$$

Replacing t by t–1 in formula (3):

$$(3')\quad P_{t-1} = \frac{a_{t-2} - 1}{a_{t-1}} P_{t-2} + \frac{A_{t-2}}{a_{t-1}} \qquad t = 2, 3, \ldots$$

Formula (3) can be written as follows, using formula (3′):

$$P_t = \frac{a_{t-1} - 1}{a_t} \left(\frac{a_{t-2} - 1}{a_{t-1}} P_{t-2} + \frac{A_{t-2}}{a_{t-1}} \right) + \frac{A_{t-1}}{a_t} \qquad t = 2, 3, \ldots$$

$$(4)\quad P_t = \frac{a_{t-1} - 1}{a_t} \times \frac{a_{t-2} - 1}{a_{t-1}} P_{t-2} + \frac{1}{a_t} \left(A_{t-1} + \frac{a_{t-1} - 1}{a_{t-1}} A_{t-2} \right) \qquad t = 2, 3, \ldots$$

While formula (3) expressed P_t as a function of P_{t-1}, formula (4) expresses P as a function of P_{t-2}. Replacing t by t–2 in formula (3) and substituting in formula (4), the equation thus obtained will express P_t as a function of P_{t-3}. And so on, until P_t is expressed as a function of the production of the base year P_0:

$$(5)\quad P_t = \frac{a_{t-1} - 1}{a_t} \times \frac{a_{t-2} - 1}{a_{t-1}} \times \ldots \times \frac{a_0 - 1}{a_1} P_0 + \frac{1}{a_t} \left(A_{t-1} + \frac{a_{t-1} - 1}{a_{t-1}} A_{t-2} + \ldots + \frac{a_{t-1} - 1}{a_{t-1}} \times \ldots \times \frac{a_1 - 1}{a_1} A_0 \right) \qquad t = 1, 2, \ldots$$

Formula (5) can be summarized as follows:

$$(6)^{1} \quad P_t = P_0 \prod_{i=0}^{t-1} \frac{a_i - 1}{a_{i+1}} + \frac{1}{a_t} \sum_{i=0}^{t-1} A_i \prod_{j=1}^{t-i-1} \left(1 - \frac{1}{a_{t-j}}\right) \qquad t = 1,2,\ldots$$

Production Policy Model

The following policy decision is taken in the base year ($t = 0$). First, the value of a_0 is exogenously determined. Second, a year T is exogenously determined ($T \geqslant 1$) so that:

$$(7) \quad a_t = a_{t-1} - 1 \qquad \text{for } t = 1,\ldots,T$$

$$(8) \quad a_t = a_{t-1} \qquad \text{for } t = T+1,\ldots$$

Formulae (7) and (8) can also be written as follows:

$$(7') \quad a_t = a_0 - t \qquad \text{for } t = 0,1,\ldots T$$

$$(8') \quad a_t = a_0 - T \qquad \text{for } t = T, T+1,\ldots$$

Formula (6) can now be written, using formula (7′):

$$(9) \quad P_t = P_0 + \sum_{i=0}^{t-1} \frac{A_i}{a_0 - i - 1} \qquad t = 1,\ldots,T$$

Formula (6) can also be written, using formula (8′):

$$(10) \quad P_t = \left(1 - \frac{1}{a_0 - T}\right)^{t-T} P_T + \frac{1}{a_T} \sum_{i=T}^{t-1} A_i \left(1 - \frac{1}{a_0 - T}\right)^{t-i-1} \qquad t = T+1,\ldots$$

Applying formula (9) for $t = T$ and substituting in formula (10):

$$(11) \quad P_t = \left(1 - \frac{1}{a_0 - T}\right)^{t-T} \left(P_0 + \sum_{i=0}^{T-1} \frac{A_i}{a_0 - i - 1}\right) + \frac{1}{a_T} \sum_{i=T}^{t-1} A_i \left(1 - \frac{1}{a_0 - T}\right)^{t-i-1} \qquad t = T+1,\ldots$$

Application of the Production Policy Model

The base year is 1980, for which $t = 0$. Thus, for example, $t = 5$ for 1985, $t = 20$ for 2000, and so on.

In order to apply formulae (9) and (11), a_0, R_0, the A_is and T need to be determined. In fact, the formulae include P_0 and not R_0, but the determination of a_0 and R_0 will automatically lead to P_0 using formula (1) for $t = 0$ (see p. 157).

R_0 and the A_is have been determined by an independent specialist commissioned by ECWA for that particular purpose. His findings are reported in Appendix 7. Now this is the crux of the matter. For the model to have any sound application at all, the level of Arab proved reserves as well as future gross additions to reserves will have to be estimated by an independent body, preferably an inter-Arab organization specially established for that purpose. This estimation work will have to be updated on a regular basis, say every two years. Thus, the future Arab production profile as derived from the application of the model at the beginning of year 0 will be revised at the beginning of year 2 in the light of knowledge acquired in years 0 and 1, and so on. The year 0 estimation work will of course determine all the P_ts ($t = 0, 1, 2, \ldots$), but the estimation of R_0 and A_0, in particular, will be of prime importance since these will determine P_0 and P_1 once and for all, while the determination of P_2, P_3, P_4, ... will only be a first approximation to be reassessed in subsequent exercises. The year 2 estimation work will likewise determine P_2 and P_3 once and for all, while the determination of P_4, P_5, P_6, ... will only be indicative, to be reassessed in subsequent exercises. Consequently, the year 0 estimation of the future production profile will only commit the Arabs for their combined output in years 0 and 1, while the outputs for subsequent years as determined by the model will only be indicative. Likewise, the year 2 estimation of the future production profile will only commit the Arabs for their combined output in years 2 and 3, and so on.

Appendix 7 only gives a sketchy illustration, limited by time and budgetary constraints, of what

[1] The convention $\prod_{j=1}^{0} = 1$ is necessary.

the independent inter-Arab estimation work described above could be. For the present application of the model, therefore, the findings reported in Appendix 7 will be used as an illustration.

For the Arab world as a whole, R_0 is equal to the difference between the current estimate of ultimate recovery Q at the end of 1979 (Appendix 7, Tables A7.8 and A7.13)[2] and cumulative crude oil production up to the end of 1979 (Appendix 3, Table A3.2):

$$R_0 = (422.80 + 59.14) - 107.60 = 374.34 \text{ Bb.}$$

Similarly, the Arab world's A_i, for any given i, is equal to the difference between the values of Q, at the end of year i and at the end of year i - 1. For example, A_0 is equal to the difference between the values of Q at the end of 1980 and at the end of 1979[3]:

$$A_0 = (428.65 + 60.82) - (422.80 + 59.14) = 7.53 \text{ Bb.}$$

Now, the allowed R/P ratio for 1980, a_0, will have to be determined by policy decision. In 1979 Arab crude output rose by more than 12 percent to an all-time record of 8.06 Bb. The reason for that increase was to compensate for the reduction in Iranian production (down 41 percent from 1978). In fact, the combined output of the Arab world and Iran was in 1979 estimated at 9.19 Bb, which is only 1 percent above its level of 1978 (9.10 Bb). In any case, the major Arab producers made it clear that the increments in production witnessed in 1979 were of a temporary nature. There is, therefore, reason to believe that P_0 (Arab crude output for 1980) will be below P_{-1} (Arab output in 1979). By how much?

The hypothetical policy decision adopted for the present exercise is to choose the integer a_0 so that P_0 will be the closest possible to, but greater than, the arithmetic average of the 1977, 1978, and 1979 production levels (7.55 Bb). Thus:

$$a_0 = 49,$$

leading to:

$$P_0 = 7.64 \text{ Bb.}$$

Finally, the year T when the R/P ratio will not be allowed to decrease any further will also have to be determined by policy decision. It is assumed here than an R/P ratio of 20 to 1 is the minimum that the Arab world as a whole would envisage today for a long period of time into the future, say 50 years. This ratio may be considered conservative by some, but it may also be justified by 1) the present state of development of alternative energy sources, about which more talk than progress has been done so far, 2) the fact that a ratio of 20 to 1 would only be an Arab average, with upward and (specially) downward variations for individual countries, the latter possibly getting close to the "technical limit."[4]

Thus:

$$a_T = a_0 - T = 20$$

leading to:

$$T = 29 \text{ (in 2009).}$$

The application of the model year by year up to 2025 is shown in Table A6.1.

MODEL 2

Notation

- t: Subscript designating year t, $t \in \{0, 1, \ldots\}$.
- R_t: Level of crude petroleum reserves at the beginning of year t, in billion barrels (Bb).
- A_t: Gross additions to crude petroleum reserves during year t, as a result of improved recovery, further development of existing fields, and new discoveries, in Bb.
- P_t: Crude petroleum production during year t, in Bb.
- a_t: Reserves to production (R/P) ratio for year t.

[2] See also Table 4.1.
[3] Ibid.
[4] This is the limit beyond which it is impossible to produce in any one year without reducing the amount of oil that can be eventually recovered. The world average for this technical R/P limit is 10 to 1 [2].

Table A6.1

Illustrative Application of Model 1: Future Crude Oil Production Profile of the Arab World (Bb).

Year	t	R	A	P	a	Year	t	R	A	P	a
1978	−2	373.14	8.45	7.18	52	2002	22	270.99	1.85	10.04	27
1979	−1	374.41	7.99	8.06	46	2003	23	262.80	1.73	10.11	26
1980	0	374.34	7.53	7.64	49	2004	24	254.42	1.63	10.18	25
1981	1	374.23	7.12	7.80	48	2005	25	245.87	1.53	10.24	24
1982	2	373.55	6.70	7.95	47	2006	26	237.16	1.43	10.31	23
1983	3	372.30	6.32	8.09	46	2007	27	228.28	1.34	10.38	22
1984	4	370.53	5.94	8.23	45	2008	28	219.24	1.26	10.44	21
1985	5	368.24	5.60	8.37	44	2009	29	210.06	1.18	10.50	20
1986	6	365.47	5.26	8.50	43	2010	30	200.74	1.11	10.04	20
1987	7	362.23	4.93	8.62	42	2011	31	191.81	1.04	9.59	20
1988	8	358.54	4.65	8.74	41	2012	32	183.26	0.98	9.16	20
1989	9	354.45	4.35	8.86	40	2013	33	175.08	0.92	8.75	20
1990	10	349.94	4.08	8.97	39	2014	34	167.25	0.86	8.36	20
1991	11	345.05	3.83	9.08	38	2015	35	159.75	0.81	7.99	20
1992	12	339.80	3.58	9.18	37	2016	36	152.57	0.76	7.63	20
1993	13	334.20	3.36	9.28	36	2017	37	145.70	0.71	7.29	20
1994	14	328.28	3.15	9.38	35	2018	38	139.12	0.67	6.96	20
1995	15	322.05	2.95	9.47	34	2019	39	132.83	0.63	6.64	20
1996	16	315.53	2.76	9.56	33	2020	40	126.82	0.59	6.34	20
1997	17	308.73	2.57	9.65	32	2021	41	121.07	0.55	6.05	20
1998	18	301.65	2.41	9.73	31	2022	42	115.57	0.52	5.78	20
1999	19	294.33	2.25	9.81	30	2023	43	110.31	0.49	5.52	20
2000	20	286.77	2.10	9.89	29	2024	44	105.28	0.46	5.26	20
2001	21	278.98	1.97	9.96	28	2025	45	100.48	0.43	5.02	20

Notes:

1. Definitions of t, R, A, P, and a are given in the "Notation" section of the appendix.
2. Gross additions to reserves accruing between 2002 and 2025 were estimated by the extrapolation of the 1978–2001 trend. Bearing in mind the Arab world's ultimate recoverable resources (see Table 4.1), the remaining gross additions to reserves yet to accrue after 2025 would be 3.17 Bb. However, see Appendix 7, pp. 166–67, for the possibility of revising upwards Arab ultimate recoverable resources.

For any t, $R_t \geqslant 0, P_t \geqslant 0$ and a_t is a positive integer.

The future is divided into two periods: the period $\{1, \ldots, T\}$ and the period $\{T+1, \ldots\}$, where T is fixed ($T \geqslant 1$). The period $\{1, \ldots, T\}$ is divided into N subperiods ($N \geqslant 1$), where n designates any subperiod, $n \in \{1, \ldots, N\}$. The number of years in subperiod n is denoted p_n. When t lies within subperiod n, it is denoted t_n. Thus:

$$t \in \{0, 1, \ldots, p_1; p_1+1, \ldots, p_1+p_2; \ldots; \sum_{i=0}^{n-1} p_i, \ldots, \sum_{i=0}^{n} p_i; \ldots; \sum_{i=0}^{N-1} p_i, \ldots, \sum_{i=0}^{N} p_i = T; T+1, \ldots\}$$

where

$$p_0 = 0$$

$$T \geqslant p_1$$

$$t_n \in \{\sum_{i=0}^{n-1} p_i, \ldots, \sum_{i=0}^{n} p_i\}$$

p_n: number of years in subperiod n (not counting the base year for period 1), $p_n \geqslant 0$, p_n integer.

y_n: rate of change of crude petroleum production, prevailing in subperiod, n, $y_n \gtrless 0$.

P_{t_n}: crude petroleum production during year t_n, $P_{t_n} \geqslant 0$.

Formulation

The idea is to establish a production profile for the first period $\{1, \ldots, T\}$ by dividing it into a number of subperiods, within each of which production changes at a constant rate (positive, nil, or negative). The production of the base year, to which the various rates of change have to apply successively, is determined exogenously to the model.

In mathematical terms:

$$(12)\quad P_{t_n} = P_0 (1 + y_n)^{t_n - \sum_{i=0}^{n-1} p_i} \prod_{i=0}^{n-1} (1 + y_i)^{p_i},$$

$$t_n \in \{ \sum_{i=0}^{n-1} p_i, \ldots, \sum_{i=0}^{n} p_i \}, \quad n \in \{1, \ldots, N\}$$

Writing the first few expressions of formula (12) will make it easier to comprehend:

$$P_{t_1} = P_0 (1+y_1)^{t_1} \qquad t_1 \in \{0, \ldots, p_1\}, \quad n = 1$$

$$P_{t_2} = P_0 (1+y_2)^{t_2 - p_1} (1+y_1)^{p_1} \qquad t_2 \in \{p_1, \ldots, p_1+p_2\}, \; n=2$$

$$P_{t_3} = P_0 (1+y_3)^{t_3 - p_1 - p_2} (1+y_2)^{p_2} (1+y_1)^{p_1}$$

$$t_3 \in \{p_1+p_2, \ldots, p_1+p_2+p_3\}, \quad n=3$$

and so on.

Production Policy Model

The following policy decision is taken in the base year (t = 0). First, the value of a_0 is exogenously determined. Second, a year T is exogenously determined ($T \geqslant 1$) so that production is derived as follows:

From formula (12) for $t = 1, \ldots, T$

From the formula

$$(13)\quad P_t = \frac{R_t}{a_T} \qquad \text{for } t = T + 1, \ldots$$

Application of the Production Policy Model

The base year is 1980, for which t = 0.

T is the year when the R/P ratio will reach a lower limit, below which it will not be allowed to decrease any further. This R/P ratio limit is chosen to be 20 to 1 for the reasons indicated in Model 1. Thus:

$$a_T = 20.$$

The period $\{1, \ldots, T\}$ will be divided into three subperiods. In the first subperiod (1981-1990) Arab crude petroleum production will be increasing by 2 percent per annum. In the second subperiod (1991-2000) growth in Arab output will be reduced to 1 percent. The third subperiod, running from 2001 to the year when the R/P ratio will reach 20 to 1 ($t = 21, \ldots, T$), will witness zero growth in production. Thus:

$$N = 3$$

$p_1 = 10$	$y_1 = 0.02$
$p_2 = 20$	$y_2 = 0.01$
$p_3 = T - 20$	$y_3 = 0$

The underlying assumption here is, of course, that $T \geqslant 21$. Otherwise, the three subperiods would have to be reduced to two subperiods (in case $11 \leqslant T \leqslant 20$, so that the first subperiod would run for 10 years and the second for T - 10 years) or even to one period of T years (in case $1 \leqslant T \leqslant 10$).

R_0 and A_is will be estimated in exactly the same manner as in Model 1, with biennial updatings. These updatings will influence the value of T, bringing it forward (in case of downward revisions in R and/or the A_is) or pushing it further into the future (in case of upward revisions in R and/or the A_is).

The value of a_0 will be determined by policy decision in exactly the same manner as in Model 1. This will allow for P_0 to be determined by dividing R_0 by a_0. Thus:

$$P_0 = R_0/a_0 = 374.36/49 = 7.64 \text{ Bb.}$$

From here on, the sequence of the model application is as follows:

1. Find R_1 using formula (2) for t = 1 (see p. 157).
2. Find P_1 using formula (12) for $t_1 = 1$ (see above).
3. Find a_1 using formula (1) for t = 1 (see p. 157).
4. Repeat steps 1, 2, and 3 above for t = 2, 3, ... until t reaches a value T such that $a_T = 20$.
5. Find R_{T+1} using formula (2) for t = T + 1 (see p. 157).
6. Find P_{T+1} using formula (13) for t = T + 1 (see above).
7. Repeat steps 5 and 6 above for t = T+2, ...

The calculations carried out according to the sequence described above yield:

$$T = 29$$

so that:

$$P_{t_1} = P_0 (1+y_1)^{t_1} = 7.64\,(1.02)^{t_1} \qquad \text{for } t_1 = 1,\ldots,10$$

$$P_{t_2} = 7.64\,(1.01)^{t_2-10}\,(1.02)^{10} \qquad \text{for } t_2 = 11,\ldots,20$$

$$P_{t_3} = 7.64\,(1.02)^{10}\,(1.01)^{10} \qquad \text{for } t_3 = 21,\ldots,29$$

$$P_t = \frac{R_t}{20} \qquad \text{for } t = 30,\ldots.$$

The application of the model year by year up to 2025 is shown in Table A6.2.

Table A6.2

Illustrative Application of Model 2: Future Crude Oil Production Profile of the Arab World (Bb).

Year	t	R	A	P	a	Year	t	R	A	P	a
1978	−2	373.14	8.45	7.18	52	2002	22	266.07	1.85	10.29	26
1979	−1	374.41	7.99	8.06	46	2003	23	257.63	1.73	10.29	25
1980	0	374.34	7.53	7.64	49	2004	24	249.07	1.63	10.29	24
1981	1	374.23	7.12	7.79	48	2005	25	240.41	1.53	10.29	23
1982	2	373.56	6.70	7.95	47	2006	26	231.65	1.43	10.29	23
1983	3	372.31	6.32	8.11	46	2007	27	222.79	1.34	10.29	22
1984	4	370.52	5.94	8.27	45	2008	28	213.84	1.26	10.29	21
1985	5	368.19	5.60	8.44	44	2009	29	204.81	1.18	10.29	20
1986	6	365.35	5.26	8.60	42	2010	30	195.70	1.11	9.79	20
1987	7	362.01	4.93	8.78	41	2011	31	187.02	1.04	9.35	20
1988	8	358.16	4.65	8.95	40	2012	32	178.71	0.98	8.94	20
1989	9	353.86	4.35	9.13	39	2013	33	170.75	0.92	8.54	20
1990	10	349.08	4.08	9.31	37	2014	34	163.13	0.86	8.16	20
1991	11	343.85	3.83	9.41	37	2015	35	155.83	0.81	7.79	20
1992	12	338.27	3.58	9.50	36	2016	36	148.85	0.76	7.44	20
1993	13	332.35	3.36	9.60	35	2017	37	142.17	0.71	7.11	20
1994	14	326.11	3.15	9.69	34	2018	38	135.77	0.67	6.79	20
1995	15	319.57	2.95	9.79	33	2019	39	129.65	0.63	6.48	20
1996	16	312.73	2.76	9.89	32	2020	40	123.80	0.59	6.19	20
1997	17	305.60	2.57	9.98	31	2021	41	118.20	0.55	5.91	20
1998	18	298.19	2.41	10.08	30	2022	42	112.84	0.52	5.64	20
1999	19	290.52	2.25	10.19	29	2023	43	107.72	0.49	5.39	20
2000	20	282.58	2.10	10.29	27	2024	44	102.82	0.46	5.14	20
2001	21	274.39	1.97	10.29	27	2025	45	98.14	0.43	4.91	20

Notes:

1. Definitions of t, R, A, P, and a are given in the "Notation" section of the appendix.
2. Gross additions to reserves accruing between 2002 and 2025 were estimated by the extrapolation of the 1978–2001 trend. Bearing in mind the Arab world's ultimate recoverable resources (see Table 4.1), the remaining gross additions to reserves yet to accrue after 2025 would be 3.17 Bb. However, see Appendix 7, pp. 166–67, for the possibility of revising upwards Arab ultimate recoverable resources.

APPENDIX SEVEN
OIL RESOURCES OF THE ARAB MIDDLE EAST AND NORTH AFRICA*

OBJECTIVE AND SCOPE

The objective of the study is to estimate the gross additions to reserves of crude oil that are likely to be made during the period extending from the present time to 2000 in the Arab Middle East and North Africa.

The term "Arab Middle East" comprises all Arab countries in Asia, i.e., all ECWA member States except Egypt,[1] and the term "North Africa" comprises Algeria, Egypt, the LAJ, Morocco, Sudan, and Tunisia.

It was proposed and agreed in discussions with ECWA officials in Beirut to present an estimate of "the sum of proved reserves and cumulative production up to any given time T," referred to henceforth as Q(T) and called by Hubbert "cumulative proved discoveries" up to time T. Gross additions to reserves during any year t can be obtained directly as the difference between the values of Q at the end of year t and at the end of year t–1.

The study is limited in scope and precision because it had to be completed within strict time and budgetary limitations. For instance, it was not possible to obtain adequate data on exploration footage drilled, which has so far proved to be the most successful single explanatory variable for ultimate recovery. Instead, the time variable was used (see pp. 165 and 168). The approach adopted, however, lends itself to periodic review and updating.

RESULTS

Various studies of world oil resources were reviewed, and the methods used were surveyed and described briefly. These methods belong basically to one of two broad categories:

1. Geological analogy with known provinces, useful for the estimation of unknown or little known petroleum provinces or basins. It is not surprising that geologists favour this approach, which requires geological experience and expertise and a good basic geological data file.

2. Study of the past record of discovery of crude oil in the basin and extrapolation of the discernable trends into the future. This method is useful for mature basins where a significant amount of exploration has been carried out and oil discoveries have been made. M. King Hubbert's estimate of oil resources by this approach is now classical. This method is favoured by the scientific and engineering communities.

With minor exceptions, all major regions of the Middle East and North Africa (main exceptions include the Red Sea, Sudan, offshore southern Arabia) can be considered to be in a mature stage of exploration and development. An engineering

*In the preparation of this appendix. Dr. Hilmi Samara, Academic Visitor, Mathematics Department, Imperial College, London (UK), acted as consultant to ECWA.

[1] The ECWA region comprises Bahrain, Democratic Yemen (PDRY), Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, the Palestine Liberation Organization, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates, and Yemen (YAR).

approach was, therefore, considered appropriate and was used in this study.

An interesting Delphic approach has also been used for the estimation of oil resources. A poll of the views and considered judgements of a broad range of experts is carried out and their answers are analysed. Like the oracles of ancient times, their judgements are accepted without the need for a scientific inquest into the methods adopted.

Table A7.6 shows estimates published since 1942 of ultimate total world resources of crude oil (inclusive of cumulative production). The estimate of Hendricks in 1965 (2,480 Bb) is the highest on the list. It is based on his assumption that the rate of discovery in barrels per exploration foot drilled will decline linearly with exploration footage drilled. The results of the exploratory record since 1965 prove that this assumption cannot be supported (see pp. 170–71).

The next highest estimate is that of Weeks in 1971 (2,290 Bb). Unfortunately, Weeks, a very experienced and most highly respected geologist, the editor of *Habitat of Oil*, is interested mainly in the comparative attractiveness of various regions of the world for exploration purposes rather than in the absolute estimates of total oil resources, and he does not publish detailed data to support his global estimates. His predictions were, in chronological order:

1948	610 Bb
1949	1,010 Bb
1958	1,500 Bb
1959	2,000 Bb
1968	2,200 Bb
1971	2,290 Bb

Taking the above remarks into consideration, there seems to be a consensus of opinion among the various studies since 1959 that total ultimate world resources of oil (inclusive of production) are about 2,000 Bb.

It is noteworthy that most of these estimates were made by the major oil companies, which have the resources, the data banks, and the interest to carry out these studies, but which, owing to the competitive nature of the industry, refrain from releasing data on which these estimates are based. Furthermore, it has been argued, with some justice, that estimates made by oil company personnel responsible for their actions to their managements tend to be on the conservative side.

The 1975 Mobil study (Moody and Esser), presented at the Ninth World Petroleum Congress in Tokyo, is worthy of note. It assesses ultimate resources of oil as follows (see Table A7.7 for details):

Worldwide	2,000 Bb
Middle East	
(inclusive of Iran)	630 Bb
North Africa	84 Bb

A survey of the Delphic poll type was recently (1978) carried out by the Conservation Commission of the World Energy Conference. A description of the methods used and the relevant results obtained is summarized on pp. 175–177. Ultimate resources of the Middle East and North Africa, considered as one unit by the study, are estimated at 829 Bb (inclusive of past production). This is well in excess of the 714 Bb estimated by Moody's Tokyo paper.

The engineering approach initiated by Hubbert and used in this paper is described briefly on pp. 169–171. The quantity Q(T), called by Hubbert the "cumulative proved discoveries," is called by the American Petroleum Institute (API) "the current estimate of ultimate recovery" and defined as "the sum of cumulative production to date and of the current estimate of proved resources." The API defines ultimate recovery as "the estimated quantity of crude oil which has been produced from a reservoir and is expected to be produced in the future. . . ." The API also tabulates the "year Y estimate of ultimate recovery," referred to in this paper as S(T, Y), which gives the estimates of ultimate recovery of fields discovered up to the end of year T based on proved reserves and cumulative production as estimated at the end of year Y. In the present study the year Y is chosen to be 1977, a fixed date, and thus S(T, 1977) is designated by S(T) for short.

Equations are derived and used to obtain a reasonable fit for the past discovery record and extrapolation to 2000 for:

1. Arab Middle East, as a whole.
2. Saudi Arabia.
3. Kuwait, Bahrain, and Neutral Zone.
4. Iraq.
5. UAE.
6. North Africa, as a whole.
7. LAJ.
8. Algeria.

Estimates of proved reserves are derived largely from either one of two sources, namely, *World Oil* and *Oil and Gas Journal*. Other annual publications, such as those from British Petroleum or DeGolyer and MacNaughton, quote these journals as their sources. Table A7.1 presents estimates of proved reserves of the Arab Middle East and shows a divergence between the two recent estimates of 48 Bb (more than 15 percent).

Table A7.1

Arab Middle East Proved Reserves (Bb).

End of Year	*Oil and Gas Journal*	*World Oil*
1977	303.8	260.4
1974	296.6	271.2
1971	311.3	286.3
1969	277.8	274.6
1963	170.0	172.8
1956	114.3	107.2

Both estimates also show optimistically high figures at the end of 1971, which decline by some 26 Bb in the case of *World Oil* estimates by the end of 1977, in spite of the fact that the gross increase in reserves in the area was considerably in excess of production during that period.

The use of published estimates of reserves for purposes of analysis of previous trends and extrapolation into the future was, therefore, avoided, and the laborious task of collecting data on individual fields with an assessment of their reserves and cumulative production at the end of 1977 was undertaken. From these data, the S(T) curve for each region and each country within it was derived, and parameters entering the theoretical derivation were obtained by trial and error to fit the observed data.

The values of S(T) and Q(T) should coincide at the end of 1977, the year of estimation on which the S(T) curves were based. In point of fact, the S(T) at the end of 1977 for the Arab Middle East turns out to be 410 Bb, compared to a Q(T) value of 378.4 Bb and 335.0 Bb given by the *Oil and Gas Journal* and *World Oil*, respectively. This paper's estimates of present reserves are, therefore, more optimistic than either, although its estimates of ultimate resources are fairly conservative.

It is of interest to compare the shapes of the S and Q curves and their difference $\Delta = S - Q$. Initially, both S and Q are equal (each has zero value); they are also equal at estimation time. The growth of Q is more even than that of S, which grows at a faster rate than Q at the beginning and at a slower rate towards the end. The graph of S looks as though it is converging rapidly to an ultimate value. This is only deceptive, because the very definition of S(T, Y) ceases to have a meaning when T is greater than Y, and, therefore, extrapolation of the curve S(T) itself beyond the base year 1977 has no meaning.

The results of the past discovery record are shown plotted in Figures A7.2 to A7.8 corresponding to the areas under study. Time is the horizontal axis while the vertical axis is S(T), the 1977 estimate of ultimate recovery of the area (in Bb). The circles are the observed points; the continuous curves are the theoretically derived fits.

The values of Q(T) for the years 1977 to 2001 are shown in Tables A7.8 to A7.15. These tables also include theoretical values of S(T) used for the history match.

Estimates for Iran, derived in a similar manner, are: 87.50 in 1977, 93.38 in 1980, 101.15 in 1985, 106.92 in 1990, 111.82 in 1995, and 114.16 in 2000.

Iran's ultimate resources of oil are estimated at 121.4 Bb.

The ultimate resources of the areas concerned are:

1. Arab Middle East 514.5 Bb

2.	Saudi Arabia	238.2 Bb
3.	Kuwait, Bahrain, and Neutral Zone	101.8 Bb
4.	Iraq	83.1 Bb
5.	UAE	71.8 Bb
6.	North Africa	87.5 Bb
7.	LAJ	56.1 Bb
8.	Algeria	23.1 Bb

Thus, ultimate resources of the Middle East (inclusive of Iran) and North Africa are:

1.	Middle East	635.9 Bb
2.	North Africa	87.5 Bb

This compares with 630 Bb and 84 Bb given by Moody in the Tokyo Congress. The total, however, of the ultimate resources of the Middle East and North Africa combined (723.4 Bb) is still some 100 Bb below the 829 Bb given by the Delphic poll survey.

This paper's estimates, though in line with Moody's (see p. 164), are believed to be on the conservative side. They probably underestimate the size of the new discoveries, especially in Saudi Arabia and the United Arab Emirates. They, above all, underestimate the undoubted great resource potential of Iraq where, to quote Dunnington: "Iraq may seem to present the greatest potentialities of any of the Middle Eastern countries for a two- or three-fold increase in estimated ultimate reserves over the next few years.... A vast additional area of Iraq awaits exploration, and a large number of delineated prospects await drilling. A high proportion of future exploration wells will be successful in locating additional 'giant' fields and a high proportion of the plains areas requires the application of sophisticated seismic investigation."

Ultimate resources of Middle Eastern countries could be as high as 250 Bb for Saudi Arabia, 125 Bb for Iraq, and 90 Bb for the UAE—giving a total of around 720 Bb for the Middle East, which is in line with the Delphic poll survey.

Ultimate resources of oil in the Middle East could, in addition, be valued upwards in due course owing to the following:

1. The contribution of small fields, which has so far been neglected as noncommercial because production costs per barrel are very much higher than the corresponding figures for the giant prolific fields of the area. This will continue to be the case until well into the next century when production costs from the giant fields will begin to rise steeply as they approach depletion. It is believed that small fields will play an important role, but their significance will be very limited during the next two decades.

2. Contrary to conventional wisdom, it is believed that recovery efficiency from Middle Eastern reservoirs will be relatively high. Recovery efficiency, as the ratio of oil recovered to the total oil-in-place, needs the value of both these quantities for its estimation.

Estimates of oil-in-place are given by the API for the USA, but very few such estimates are available for the Middle East to allow sound analysis and firm conclusions. However, petroleum and reservoir engineering sciences were well established before any significant production from the Middle Eastern oil fields took place. The producing fields are normally giants run as a unit by a single authority with well established petroleum engineering and reservoir engineering departments and attendent laboratories for adequate reservoir control. Kirkuk oil field's development has been a remarkable example of the scientific control possible in a major reservoir and an excellent representative of the fractured limestones of northern Iraq and Iran. Massive water injection started in the late 1950s, monitored by a ring of observation wells to measure pressures, oil water levels, gas/oil levels, and saturation pressures to a very high degree of accuracy. These formed the basis for extensive reservoir simulation studies, allowing accurate estimates of recoveries to be made and showing that inbibition can be a very efficient production mechanism. Similar water injection schemes were initiated into the fractured Asmari limestones of Iran, with comparable recoveries expected.

Another example, this time from the LAJ, will suffice here. This is the remarkable speed of development of the Intisar fields:

March	1966	Concession granted.
April	1967	First well drilled–discovered Intisar A.
September	1967	Third well drilled–discovered Intisar C.
October	1967	Fourth well drilled–discovered Intisar D.
February	1968	Production started upon completion of 135 miles of 40-inch pipeline together with terminal facilities.
July	1968	Water injection started.

Over 1 Bb were produced by mid-1975 from Intisar A and D. These fields, although possibly over-produced in the first few years, are likely to have high recovery efficiency since pressure maintenance and miscible gas injection were introduced early in the life of the field.

Enhanced recovery methods of oil production, which are still in the pilot stages of development, are extremely expensive per barrel and require considerable lead time for implementation. On both counts, this paper does not foresee the implementation of tertiary or enhanced recovery methods in the Arab world until well into the next century, possibly simultaneously with interest in smaller fields.

ASSUMPTIONS

The basic assumptions underlying the engineering approach are plausible and, since they are extrapolations of past trends, they are in conformity with historical records. These assumptions are:

1. The rate of discovery of new fields (in terms of Bb per year or in terms of barrels per unit of exploration effort) decreases with time. This is quite reasonable since the rate of discovery can be assumed to be a function of the remaining undiscovered resources, leading to the familiar exponential decay with time (or with exploration effort).

2. The current estimate of ultimate recovery of a field grows with time as a result of step-outs extending the area of the field horizontally or of deeper wells extending it vertically. Advances in production technology that increase recovery efficiency (the proportion of oil-in-place that can be produced) also plays an important role in this growth process. The growth of the current estimate of ultimate recovery of a field towards its ultimate recovery is also exponential.

A number of factors can conceivably alter the picture dramatically, but the probability that this will actually happen before the end of this century is not very high. Also possible are such fundamental changes as:

1. A breakthrough in exploration techniques that would allow the identification of stratigraphic traps. Most of the oil discovered in the Middle East is in structural traps, which are detectable by seismic techniques. Identification of stratigraphic traps requires a high density of wells to allow detailed geological study and correlation. Wildcat well density in the Arab world is about one per 500 square miles (compared to one per 5 square miles in the USA). This wildcat well density is not likely to be changed dramatically over the next two decades. It is, however, interesting to note that an experimental 3D offshore seismic survey was conducted in Saudi Arabia, and research onshore to determine the possibility of oil and gas detection by the measurement of natural energy from the ionosphere is also underway. The practical engineering approach of extrapolating trends would tend to underestimate the contribution of major changes in exploration techniques. On the other hand, the opposite extreme argument that abundant oil resources exist in stratigraphic traps, which escaped detection so far because they are difficult to detect, is not an appropriate basis for meaningful planning purposes.

2. The discovery of a huge new province in the Middle East or North Africa on a scale unsuspected at present.

3. A breakthrough in the economics of enhanced recovery, which could dramatically increase the amount of reserves from already discovered fields, whether depleted or still

producing, and from fields to be discovered in the future. On average, recovery factors are about one-third, and thus on depletion two-thirds of the oil originally in place is left in the ground. A 5 percent increase in the recovery factor, still leaving some 62 percent of the oil underground when the fields are abandoned, would increase ultimate recovery by 15 percent of existing estimates. In the Middle East, this increase amounts to 100 Bb—roughly the equivalent of another Kuwait.

The estimates obtained in this study deal with the resources of oil only and do not include gas resources.

RECOMMENDATIONS

1. The creation of files about the various technical phases of the oil industry in the Arab world, initially from published data, is needed, with a view to eventual verification from official sources whenever possible. Among them:

(a) Exploration activity including surface geology, seismic surveys, onshore and offshore, exploration wells and footage drilled, discoveries obtained, etc.

(b) Development and production from individual fields: to include development drilling (number of wells and footage drilled), number of producing wells, production mechanism (flowing, pumping, gas lift, etc.), production rate, cumulative production, reservoir studies carried out, production facilities installed (water injection, gas injection, separation of produced water, dehydration, desalting, etc.), estimate of reserves, properties of crudes, etc.

(c) The statistical data files should include gas as well as oil statistics.

The ideal, of course, would be an authoritative document, issued annually by a body set up specifically for the purpose to collect and verify the above data. The value of the results obtained would depend to a considerable degree on the cooperation of the oil industry in the Arab world.[2]

2. The use of time as the independent variable needs to be replaced by the use of a more meaningful yardstick that measures the exploration effort. In this connexion, the total exploration footage drilled, a measure originally advocated by Zapp, is commonly utilized. Although far from being ideal, since it leaves out of account the enormous effort put in by geophysical work and geological studies and interpretation, on the one hand, and by the knowledge gained through production history, reservoir studies, etc., on the other, this single measure has been the most successful to date.

It was not possible to obtain adequate data on exploration footage. Even the number of exploration wells drilled annually were only estimates. The American Association of Petroleum Geologists (AAPG) publishes such estimates for North African countries but refrains from doing so for some of the countries in the Middle East. Time limitation prevented a more thorough search of the literature to obtain an internally consistent set of data adequate for this purpose.

A possible alternative is to use the total number of wells drilled or the total footage drilled, which is much more easily available. The total footage drilled is roughly five times the total exploration footage drilled, thus cumulative footage drilled could be used as an independent variable. Yet another available alternative is to use the number of dry holes drilled annually.

It is, therefore, recommended that these various alternatives be examined with a view to obtain a more accurate fit of the historical data and, hence, a more reliable estimation.

3. Another fruitful line of research into the subject is to subdivide the area into geologically similar provinces and possibly major stratigraphic units. The tertiary fractured limestones of northern Iraq

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[2] In Chapter 4 (p. 37), it was suggested that an inter-Arab body be established for the purpose of assessing the level of Arab proved oil reserves and future growth additions to proved reserves. The mandate of this body could be extended so as to cover the data files mentioned above.

can be grouped with the onshore Iranian fields of Asmari fractured limestones. Southern Iraqi fields of Cretaceous sandstones form a province with the fields in Kuwait and possibly with some of the offshore fields in the Gulf. The prolific fields onshore Saudi Arabia consist of thick upper Jurassic limestones, while most reservoirs in Abu Dhabi are thick limestones of Lower Cretaceous age. The statistical data on drilling, production, and reserves will then have to be grouped according to the new subdivisions, and an analysis will have to be carried out on each with a view to improving the quality of forecasts.

4. A review of crude oil and gas reserves and crude oil and gas resources of the area should be produced periodically, perhaps on an annual basis. This task could be entrusted to the inter-Arab body mentioned in recommendation 1 above.

METHODOLOGY

This section gives a brief description of the engineering method developed by M. King Hubbert and derives the equations used in this paper to obtain the theoretical curves plotted in Figures A7.2 to A7.8.

Let: P(t) be the cumulative production up to the year t and
R(t) be the proved reserves as estimated at the end of year t and define:

$$Q(t) = P(t) + R(t),$$

where Q(t) is the "cumulative proved discovery" (Hubbert) or the "current ultimate recovery" (API). Both P and Q exhibit the familiar S curve common to growth phenomena. They can only grow with time, start from zero at the beginning, and tend to an ultimate value Q at the end.

The curve of proved reserves R is bell-shaped, starts at zero, rises to a maximum, and declines again to zero. When reserves R at time t are sufficient for n years of production at a sensibly constant rate, then it is clear from the definition that:

$$R(t) = P(t+n) - P(t).$$

Hence:

$$P(t+n) = R(t) + P(t) = Q(t),$$

which explains the empirical result obtained by Hubbert that the Q curve will resemble the cumulative production curve shifted to the right n years along the t axis. In the USA during the 1950s and the 1960s, n was equal to 10-12 years, roughly the reserves to production ratio, as to be expected from the above formula.

Let the fields discovered during year t have ultimate recovery q(t). The estimate carried out during year s of the ultimate recovery q(t, s) of these fields grows with time s and approaches asymptotically its ultimate recovery value of q(t) as s becomes very large. The approach towards this value is exponential, as common to many growth phenomena:

$$q(t,s) = q(t)\left[1 - \frac{G-1}{G}\exp(-b(s-t))\right].$$

When s is very large q(t, s) approaches q(t), and when $s = t$: $q(t, t) = q(t)/G$.

Thus, G is the growth factor of estimated ultimate recovery from the year of discovery to depletion.

Let us consider the integral:

$$S(T,s) = \int_0^T q(t,s)\,dt.$$

where s is greater than or equal to T. S(T,s) would then be the estimate of ultimate recovery carried out at the end of year s, for all the fields discovered up to the end of year T.

Where $s = T$, it is quite clear that S(T, T) equals the current ultimate recovery:

$$S(T,T) = Q(T).$$

The ultimate recovery of the fields discovered up to year T is given by:

$$D(T) = \int_0^T q(t)\,dt.$$

New discoveries at any time will be given by the derivation of D(t) with respect to time, while gross discoveries will be given by the derivation of Q(t) with respect to time.

The derivation of S with respect to time can be used to obtain an estimate of q(t), the ultimate recovery from fields discovered in year t. In fact:

$$q(t) = \frac{dS(t,s)}{dt} \;/\; [\,1 - \frac{G-1}{G} \exp(-b(s-t))\,].$$

The net discovery rate q(t) is expected to decrease exponentially with time (or more precisely with exploration effort). In this case:

$$q(t) = q \exp(-ct).$$

Then S(T, s) and Q(T) will be given by:

$$S(T,s) = D(T) - q \frac{G-1}{G} \exp(-bs)\,[\exp(b-c)T-1] \;/\; (b-c)$$

$$Q(T) = D(T) - q \frac{G-1}{G} \exp(-bT)\,[\exp(b-c)T-1] \;/\; (b-c)$$

and $D(T) = (1 \exp(-cT)) / c.$

There are five parameters involved: q, G, b, c, and the year determining the zero time.

It is of interest to note that the difference Δ between S and Q is given by:

$$\Delta(T,s) = q \frac{G-1}{G} [\exp(-bT) - \exp(-bs)]\;[\exp(b-c)T-1] \;/\; (b-c).$$

It is noted that Δ starts at zero for T = 0, quickly grows to a maximum, and declines again to zero as T approaches s.

It is further noted that:

$$\frac{dQ}{dT} = q(0,T) - c\,Q(T).$$

The fact that the first term on the right hand side increases with time T at least partly offsetting the increase in the second negative term, explains the reason why Q(t) grows more evenly with time.

Generally, the shapes of Q, P, and R are as shown in Figure A7.1.

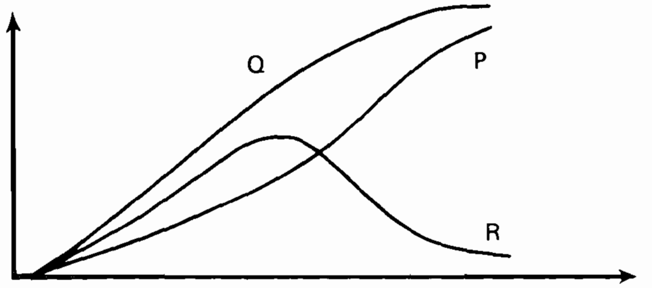

Figure A7.1. The Q, P, and R curves.

At this point a review of both the engineering approach used by Hubbert, Zapp, and Hendricks and their assumption regarding efficiency of exploration is in order.

Hubbert examined the rate of change of R, P, and Q. He found that for the USA reserves R grew steadily until 1961 then began to decline, while curves Q and P had a point of inflexion each (where the rate of change increases up to the inflexion point and decreases afterwards). The point of inflexion of Q occurred in 1957, while the point of inflexion of P was expected in 1969. Hubbert assumed that the point of inflexion occurred when Q attained half its ultimate value. This gave an ultimate recovery of 171 Bb for the USA excluding Alaska.

This assumption depends on the shape of the Q curve. It was challenged by C.L. Moore, who used a Q curve whose inflexion point occurred when Q attained one-quarter of ultimate value, and who was thus led to twice the reserve attained by Hubbert.

A different and more positive approach based on the efficiency of exploration was suggested by Zapp and used by Hendricks and Hubbert. The results obtained by Hubbert using this approach are in conformity with those obtained by him using the assumption about the shape of the Q curve.

Zapp suggested cumulative exploration footage instead of time as the independent variable and assumed that saturation exploration drilling is represented by a wildcat density of half a well per square mile, drilled either to the basement or up to 20,000 feet. He estimated that this represented 5 billion feet of exploration drilling.

Hendricks added Alaska to increase this to 7 billion feet.

Zapp estimated exploration footage drilled by the end of 1961 to be 1.1 billion feet and estimated ultimate resources discovered up to that date at 130 Bb, an average of 118 barrels per foot.

Zapp assumed this discovery ratio to continue at this level up to the 5 billion feet of exploration wells drilled and, thus, obtained ultimate resources of the USA as:

$$118 \times 5 = 590 \text{ Bb.}$$

It is interesting to note that by the end of 1975 approximately 2 billion exploration feet were drilled, while the estimated ultimate resources discovered up to that date were 154 Bb. Thus, in the 15-year period 1960–1975, 0.9 billion exploration feet were drilled to discover an additional 24 Bb, an average of 27 barrels per exploration foot, compared to the 118 barrels per foot prior to 1960.

Hence, the hypothesis of Zapp of a nearly constant discovery rate per exploration foot drilled is untenable.

Hendricks assumed that discovery rate per exploration footage drilled would decline linearly with time to zero at 7 billion exploration feet drilled. The average rate for the second billion exploration feet should, therefore, have been 106 barrels per exploration foot, which is still very high when compared to the 27 barrels per exploration foot observed. Hence, the hypothesis of Hendricks and the resulting high estimates cannot be supported.

DATA BASE

Introduction

Detailed information exists in the USA and Canada regarding exploration effort, discoveries made, wells drilled, proved reserves, growth of reserves of discovered fields, etc.

In the Middle East and North Africa this, unfortunately, is not the case. In the heyday of the oil companies almost all information was strictly confidential. Anything to do with exploration, well logging, production tests, etc. was kept secret. But the most holy of holy secrets was any information about reserves; free access to reports about reserves was sometimes almost denied to the authors of the reports.

With the rising tide of control of their oil industry, the host governments in the Arab world inherited, among other things, this attitude to reserves. To quote the *Oil and Gas Journal,* December 1976:

"Politics stood in the way of the Journal's annual worldwide survey of oil and gas reserves. Some countries maintained statistics as national secrets, forbidding, sometimes under the penalty of death, their disclosure.

As a result, some of the statistics are estimated, with the Journal using primary sources such as private operating companies and highly reliable geological experts. Some state companies like INOC and ADNOC declined to respond to the Journal's request for information."

Production statistics are sometimes not available for a country as a whole, let alone broken down by fields, even to the prestigious bulletin of the AAPG.

Estimates of reserves of discovered fields can be scaled upwards or downwards for other than technical reasons. Two examples will suffice here:

1. "There is little temptation to belittle discoveries when the principal problem facing the successful discoverer is the raising of vast funds to pay for development in a very difficult and costly operating environment."

2. "Saudi Arabia was a big loser in crude sales in 1975. Aramco had a capacity of 11 Mb/d, an allowable of 8.5 Mb/d, but sales did not exceed 7 Mb/d. Tapline with a capacity of 0.5 Mb/d was shut down for lack of customers." (*Oil and Gas Journal*, December 1975).

"The most significant revision of reserves is the Saudi Arabian Government huge cutback in its own estimate last year of 148.6 Bb. Without explanation, the Assistant Deputy Minister for Technical Affairs announced oil reserves of 107.832 Bb. This is almost exactly the same as Aramco's 107.857 Bb reported the same day. At the same time gas reserves plummetted from 103 Tcf to 62.29 Tcf."

"It seems previous estimates were scaled up for political reasons; and now the Government is taking over Aramco, the Government finds the lower figure more expedient for political reasons." (*Oil and Gas Journal*, December 1976).

Estimates of ultimate resources can be influenced, at least subconsciously, by the objective of the exercise.

Most oil company studies have been orientated towards determining where in the world to find new oil/gas reserves that could be developed and produced economically within a ten-year span.

Lewis G. Weeks puts it more forcefully:

"Resource estimations are aimed at efficiency in spending the exploration budget.... Comparison of basins or countries is primarily for investment purposes and not to obtain the absolute value in any given basin, but rather to obtain the relative attractiveness of one area over another."

Michel Halbouty, the distinguished and eloquent advocate of the American petroleum industry, believes that "the business of predicting the known—i.e., petroleum resources estimation—is important, it will affect the developing national energy policy." He preaches against the pessimistic conclusions drawn from extrapolating the past and against predicting by analogy since this could imply that the remaining life of the domestic exploration industry of the USA—particularly onshore—is short, perhaps ten years. Halbouty believes, and he has had four decades of experience in the evaluation of US petroleum resources, in a new frontier of oil exploration in the USA, where new concepts can be developed, where the emphasis is shifted from the search for structural traps easily detectable by seismic survey to the much more subtle and therefore difficult to discover stratigraphic traps, which, with the development of new exploration tools, will all confirm that the USA contains considerable petroleum resources awaiting discovery.

The spectacularly optimistic Peter Odell would wish to convince us that the case for energy shortage and "traumatically increased" prices of energy have not been proven and that estimates of world oil resources should be nearer the 4,000 Bb mark rather than the "accepted" 2,000 Bb. He sees "in the North Sea an abounding source of oil for the future, that would rid Western Europe, for decades, of dependence upon Middle Eastern and African oil."

The *Oil and Gas Journal*, in its last issue of the 1960s, predicted for the 1970s: "We predict the discovery of great oil fields in the North Sea.... Demand for Middle East and even African oil will dwindle."

The problem of estimating undiscovered resources—predicting the unknown as Halbouty would have it—contains an element of subjective judgement, which could be swayed by the purpose for which the estimates are being prepared. An instance comes to mind where a production system was installed, complete with degasing station, housing, club facilities, transfer line, etc., only to discover the reservoir in question capable of sustaining about 15 percent of the installed production capacity.

It would be quite wrong to be over optimistic when such an attitude could lead to the over committing of resources unnecessarily. It would be equally wrong for a Halbouty to be anything but optimistic as long as pessimism is likely to put a break on exploration before it ceases to be profitable.

This paper's predictions of the values of Q(T) have been given to a large number of significant figures, not to claim such a high degree of accuracy, but to retain the smooth character of the predictions and to avoid the introduction of spurious effects resulting from rounding off errors.

Data Used

Data available varied from one country to another and from one year to another. Saudi Arabia's published information was probably the most complete for the Middle East. The collected data included (see References, p. 186):

1. Annual proved reserves given by *World Oil* and the *Oil and Gas Journal* from 1953 to the end of 1977.

2. Cumulative production for the country as a whole from OPEC statistics.

3. Individual fields, onshore and offshore, their year of discovery and estimates of reserves, as published by the AAPG bulletin at the end of 1972 and 1975 and by Richard Nehring's study.

4. Annual estimates of the International Petroleum Encyclopedia of cumulative production and remaining reserves of individual fields.

5. Cumulative production at mid-year of individual fields as published by the *Oil and Gas Journal*.

6. Age of reservoir rock, depth of producing horizons, number of flowing wells, and other pertinent production information as published by the *Oil and Gas Journal*.

7. Information concerning exploration activity (seismic onshore and offshore), exploration wells drilled, success ratios, etc., mainly from the AAPG bulletins.

8. Information concerning production plans, installation of production facilities, water and gas injection facilities, oil and gas separation facilities, dehydration and desalting facilities, etc., mainly from *World Oil*, the *Oil and Gas Journal* and *International Petroleum Encyclopedia*.

As a result of this collected information, a tabulation of individual fields by year of discovery was arrived at, together with an estimate of the reserves of each. Nominal values were accepted for the newer discoveries, where little information was available. This tabulation covered all the history of oil production in each country of the Middle East (inclusive of Iran) and North Africa.

S(T) for each country was derived as a function of T by the summation of all discoveries since the start of exploration up to the end of year T.

GEOLOGICAL METHODS OF RESOURCE ESTIMATION

Background

A theory that explains the origins and present distribution of crude, the habitat of oil, is necessary to estimate the volumes of crude oil that are likely to be discovered in the future. The presently accepted theory, supported by overwhelming evidence, is the organic origin of petroleum.

During geologic history, a minute fraction of the organic matter of former plants and animals became buried under conditions of incomplete oxidation in sedimentary muds and limes. These source beds were subjected to high temperature and pressure during geologic time. The high temperature cooked the organic matter to produce some form of crude oil, and the pressure slowly compacted the muds and limes to shales and limestones, squeezing the crude oil out and gradually reducing their ability to transmit liquids (permeability).

Petroleum, thus expelled, was forced to migrate in the direction of the prevailing forces, which tend to be generally in the upward direction. Eventually petroleum reached the earth's surface, or was prevented from doing so by a subsurface trap, and, thus, accumulated as an oil field.

Petroleum, thus, originates in a chemically reducing environment in organic thick shales or carbonates that were deposited as muds or limes. But petroleum is found today in porous and permeable reservoir rocks that were most commonly deposited in well oxygenated environments from which muds were removed.

Environments favourable for source bed accumulation are not favourable to reservoir rock formation, and vice versa. No oil can occur until source and reservoir rocks coexist in a proper relationship both in space and time.

The rate of deposition is an important factor in preserving organic matter from bacterial oxidation. Hydrocarbons may be effectively preserved by rapid burial. The rate of deposition in the central part of a basin may be so slow as to permit bacterial destruction of organic matter.

The incidence of oil is greater in those reservoir rocks deposited over highs that lie within or adjacent to depressions in which the environment was favourable for the accumulation of source beds. The yield per unit volume of sediment in a basin decreases towards the stable interior of a continent and has its maximum at the basin "hingebelt."

Thus, the best conditions for both the source of organic matter and its preservation lie in the intermediate basin flank where it is an optimum balance between the rate of sedimentation, the temperature gradient, and other aspects of the environment.

The time required for the formation of hydrocarbons by these geological processes is about 600 million years, while the time it takes to consume them is no more than a couple of hundred years. Consequently, hydrocarbon resources can be considered to consist of fixed initial supplies, which are continually diminished during the period of their exploitation. The quantity remaining in the ground at any time must be equal to the difference between the quantity initially there prior to the start of production and the cumulative production up to that time.

Geological Methods

The organic theory of matter is in conformity with the fact that petroleum is now found only in or adjacent to basins filled with sedimentary rocks. The geological location and extent of the sedimentary basins in the land areas of the world are now well known. Most of the geologists in the world are engaged in the exploration for petroleum, and the amassed knowledge of the geology of petroleum and of the sedimentary basins of the world is now extensive.

Table A7.2 below shows the area of the sedimentary basins in various parts of the world, together with the total number of wells drilled, exploration wells drilled, etc. It is quite clear that there is a very marked imbalance in the data base between, on the one hand, the Middle East and North Africa and, on the other hand, the USA where the density of wells per square mile is two orders of magnitude higher than in the Middle East.

A basin or province is the basic regional geologic unit for petroleum exploration. Basins can vary in size, ranging from very large areas like the Arabian Iranian basin to quite small areas like the Gulf of Suez basin.

There are at least 400 known basins in the world, both on land and offshore. Of these, 275 basins have been subject to some exploration effort. Of the remaining 125 basins, some 70 are either deep ocean basins or in the polar region.

The Arabian Iranian basin is unique among basins. It contains more than half the known reserves of the world. It has 23 of the 33 recognized super giant fields (more than 5 Bb of reserves).

The geological appraisal of the petroleum potential of a new province is carried out largely by analogy with known provinces. This involves:

1. Computing the petroleum resources of intensively explored provinces.
2. Dividing those provinces into categories.
3. Assigning inadequately explored provinces to similar categories.
4. Calculating resources by using factors established for the geologically similar regions.

Table A7.2

Résumé of World Prospective Areas (onshore and offshore to 600 feet of water depth).

	Million Square Miles	Total Wells	Average Depth, in Feet	Wildcats
USSR	3.5	530,000		100,000
USA	2.5	2,425,000	4,231	482,000
Canada	1.9	100,000	4,056	20,000
Middle East	1.2	10,000	6,294	2,000
World	24.5	3,233,000		645,000

For example, the geology of the coastal region of Nigeria was found to be similar to that of the coastal region of Texas and Louisiana. By analogy, it was assumed that the Nigerian sediments would probably contain a quantity of oil per unit volume comparable to that which was discovered in the Texas-Louisiana Gulf coastal region. Subsequently, drilling in Nigeria confirmed this assumption.

The difficulty of this method is the subjective determination of the adequately explored regions and the geological factors considered critical for comparative purposes.

Each basin is, in some sense, unique, and there is, unfortunately, a lack of correlation between the obvious geological parameters and petroleum resources (per cubic mile) in well explored basins. Thus, this comparison technique is unlikely to produce estimates with any useful degree of accuracy in a given unexplored province. The estimated resources should have a more acceptable degree of accuracy if several (say 20) unexplored basins were considered together for their total resource expectation.

Shell analyzed the sedimentary basins of the world in an effort to find a relationship between the type and content of recoverable petroleum. They have not succeeded in developing any systematic relation between recoverable hydrocarbons and 1) basin thickness, 2) areal extent, and 3) sediment volume.

Potential productivities of basins range from 1,000 barrels to several million barrels of oil per cubic mile of sediment. Yield per proved acre varies from a few hundred barrels to a million barrels per acre, with an average of some 35,000 barrels per acre. The percentage of the basin that will yield proved average varies between 0.1 percent to 5 or even 10 percent, with an average of 0.5 percent.

Very few, if any, of the published oil resource estimates show the details on which these estimates are based. The data are confidential due to the competitive nature of the oil industry. It is, therefore, difficult to verify them in the usual scientific manner, and, hence, they are subject to some suspicion. This explains the faith expressed by engineers in M. King Hubbert's approach, where all the data and assumptions are clearly spelled out.

It is, however, remarkable how closely the estimates of ultimate petroleum resources of the world do agree around the figures of 2,000 Bb.

In practice, geological methods vary in their detailed application. A region that is judged to be a single habitat of oil is used. For instance, the USA (without Alaska) is divided into 68 provinces and 30 major stratigraphic units. A dry hole is considered to condemn a volume of rock equal to that occupied by the average pool in the province and stratigraphic unit analyzed. Thus:

$$U = F \times \frac{\text{Potential volume}}{\text{Drilled volume}} \times R,$$

where:

U = Undiscovered resource,
R = Discovered reserves,
F = Richness factor.

Potential volume is the sedimentary rock volume that seems capable of production but is not drilled so far, while the drilled volume is the volume of producing pools plus the volume condemned by dry holes.

Geological expertise and experience are necessary to estimate potential volume from the knowledge of the basin and to estimate the richness factor F, which experience shows to be less than one-half.

Statistical analysis and a probabilistic examination of the necessarily subjective judgements involved in geological methods of resource estimation have been used to improve on the best guess approach. Basic data are presented as probability curves. A simulation process involving random sampling from these probability curves leads to a future resource probability curve.

THE DELPHIC APPROACH TO RESOURCE ESTIMATION

An interesting approach was recently (1978) carried out by the Conservation Commission of the World Energy Conference and published under the title: *World Energy Resources 1985-2020: Oil and Gas Resources.*

A poll of the Delphic type appeared to be the best way to answer the questions posed concerning oil and gas resources.

Forty-two of the most highly qualified and worldwide experienced experts were selected, representing all shades of opinion from among specialized official services, international petroleum companies, national and independent petroleum companies, consultants, and individual experts.

The poll was carried out between September 1976 and April 1977. Questions that involve long-term predictions and complex elements of judgement and experience and that "cannot be answered by calculation, the extension of existing curves, or analytical reasoning" were put to the experts. Some 30 answers were received and analyzed.

The questions, 11 of them, included the ultimate recoverable crude oil resources of the world broken down by region and the future rate of crude oil discovery (net and gross) for the world as a whole.

Recoverable resources estimated at the end of 1975 were defined to exclude past production and to aim for the technical maximum recoverable resources on the assumption that the cost per barrel of oil would tend towards $20 per barrel (at constant 1976 dollars) by 2000 (this cost representing the technical cost exclusive of taxes and profits). It is interesting to note that the views of the experts were that their answers would not have been affected if the cost per barrel were $12 or $40.

It was further assumed that there are no financial, economic, political, or ecological obstacles to exploration and production and that there will be sufficient funds, manpower, and government authorization to prospect for and develop all favourable zones as thoroughly as possible.

The answers received were divided into three classes:

Class I: three replies, the pessimistic estimates
Class II: 15 replies, the majority
Class III: five replies, the optimistic estimates

Table A7.3 below summarizes the results obtained for recoverable resources at the end of 1975 (converted from the units used to Bb using a conversion factor of 7.33).

Table A7.3

Results, by Class, of Answers to Questions on Reserve Estimation (Bb).

	Class I	Class II	Class III	Average
USSR and China	386	399	555	435
USA and Canada	140	191	287	209
Middle East and North Africa	495	747	1,071	800
Rest of Africa	33	65	156	83
Western Europe	76	81	86	82
Latin America	97	153	237	168
Total World (excluding deep offshore and polar regions)	1,185	1,750	2,540	1,886
Deep Offshore and Polar Regions	21	155	684	284

Table A7.4

Details of Answers to Questions on Reserve Estimation: Middle East and North Africa.

Class	Identification Number	Bt	Bb
I	1	(57.5)	(421)
	2	80.3	588
	3	54.8	402
Class Average*		67.5	495
II	4	85	623
	5	76	557
	6	103	755
	7	103	755
	8	87.7	643
	9	112.5	824
	10	82.4	601
	11	156	1,143
	12	77.7	570
	13	90	660
	14	119	872
	15	134.3	984
	16	110	806
	17	90	660
Class Average		101.9	747
III	23	122.5	898
	24	118.3	867
	25	100	733
	26	90	660
	27	300	2,200
Class Average		146.2	1,071
Overall Average		109.1	800

*Answer 1 was excluded from the average.

Table A7.5

Discoveries (Bb per year).

Year	Gross	Net
1985	28.5	16.9
2000	20	8.8

Table A7.3 gives the remaining recoverable resources at the end of 1975. World cumulative production of 337 Bb up to that date must be added to obtain ultimate recoverable resources of 2,087 Bb for the world.[3] The corresponding figures for the Middle East and North Africa are 846 Bb, and for the USA and Canada 308 Bb.

Detailed answers for the Middle East and North Africa are given in Table A7.4.

The classes above were devised to accommodate the answers concerning the reserves of the world as a whole; they may not be very appropriate for the Middle East and North Africa region on its own. There is only one estimate that is way out at 2,000 Bb, about three times the average. Deleting this very high estimate leaves an average of 730 Bb for the Middle East and North Africa region.

The answers for the region were also reclassified into three classes according to increasing estimates:

Class (i): the four lowest estimates.
Class (ii): the estimates ranging from 588 Bb to 898 Bb.
Class (iii): the three highest estimates.

The average for class (ii) was also found to be 730 Bb. Adding cumulative production to this estimate, the ultimate resources become 829 Bb for the Middle East and North Africa.

The answers and comments regarding future oil discoveries were based on:

1. Net discoveries: discoveries of new fields.
2. Reevaluation of reserves in existing fields.

Gross discoveries are the sum of the two items above.

The question was one of the most important and difficult. A very large majority anticipated that future gross discoveries would decline from 1985 to 2000; the general feeling was that most of the discoveries would occur before 2000.

Published figures bear out the statement that more oil was discovered in new fields in the early 1960s than in the early 1970s. Table A7.5 represents the average view of the 22 replies.

[3] World excluding deep offshore and polar regions: 1,750 (from Class II) + 337 (past production) = 2,087 Bb.

Table A7.6

Ultimate World Resources of Crude Oil.

Year	Source	Bb
1942	Pratt, Weeks, and Stebinger	600
1946	Duce	400
1946	Progue	555
1948	Weeks	610
1949	Leverson	1,500
1949	Weeks	1,010
1953	McNaughton	1,000
1956	Hubbert	1,250
1958	Weeks	1,500
1959	Weeks	2,000
1965	Hendricks (US Geological Survey)	2,480
1967	Ryman (Esso)	2,090
1968	Shell	1,800
1968	Weeks	2,200
1969	Hubbert	1,350–2,100
1970	Moody (Mobil)	1,800
1971	Warman (BP)	1,200–2,000
1971	Weeks	2,290
1975	Moody and Esser (Mobil)	2,000
1978	World Energy Conference	2,087

Source: References 4, 5, and 6 of this appendix (p. 186).

Table A7.7

Proved Reserves, Cumulative Production, and Ultimate Resources (Bb).

	USA	Canada	Middle East	North Africa	World
1. Proved reserves (end of 1973)					
Oil and Gas Journal	34.7	9.4	350.2	39.2	627.9
World Oil	35.3	9.3	316.0	35.6	546.3
US Geological Survey	45.4	10.2	360.1	41.9	633.4
Warman (BP)	33.1	6.8	335.0	20.5	570.0
2. Cumulative production (end of 1973)	103	7	69	13	297
3. Proved and probable reserves of fields discovered by end of 1973	51	7	430	33	740
4. Ultimate reserves of fields discovered by end of 1973 (2 + 3)	154	14	499	46	1,037
5. Undiscovered potential (end of 1973)					
Onshore	29	13	104	30	585
Offshore	47	58	27	8	378
Total	76	71	131	38	963
6. Ultimate resources (4 + 5)	230	85	630	84	2,000

Source: Reference 6 of this appendix (p. 186).

Table A7.8
Estimates of Ultimate Recovery: Arab Middle East (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	410.0	410.0	1977	410.00
1976	409.7		1978	416.59
1975	406.6	408.6	1979	422.80
1974	404.8		1980	428.65
1973	400.4		1981	434.17
1972	397.5		1982	439.35
1971	396.6		1983	444.23
1970	390.8	397.5	1984	448.81
1969	390.2		1985	453.12
1968	385.4		1986	457.16
1967	382.2		1987	460.95
1966	373.1		1988	464.51
1965	370.8	374.2	1989	467.84
1964	355.6		1990	470.96
1963	334.5		1991	473.89
1962	325.8		1992	476.62
1961	314.8		1993	479.18
1960	307.2	333.2	1994	481.58
1959	305.0		1995	483.82
1958	301.4		1996	485.92
1957	296.4		1997	487.87
1956	277.2		1998	489.70
1955	269.6	266.5	1999	491.41
1954	261.4		2000	493.00
1953	251.7		2001	494.49

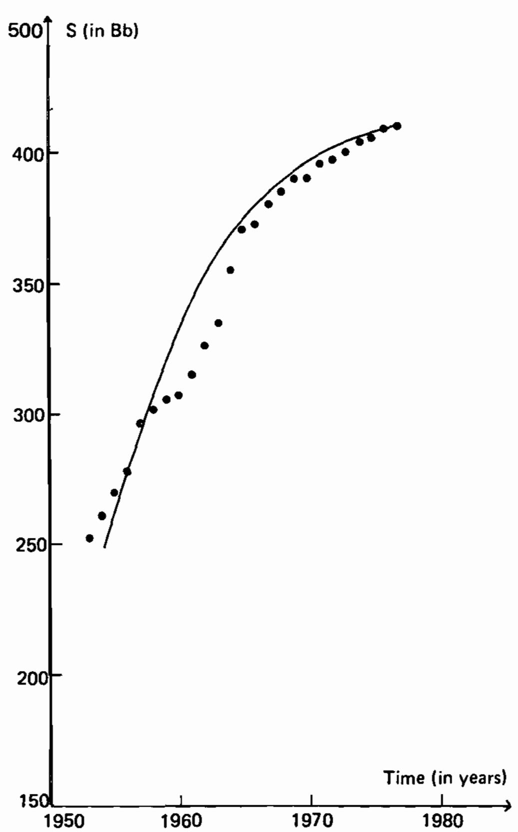

Figure A7.2. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: Arab Middle East.

Table A7.9
Estimates of Ultimate Recovery: Saudi Arabia (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	189.8	189.80	1977	189.80
1976	189.8		1978	192.85
1975	188.8	188.90	1979	195.75
1974	187.3		1980	198.45
1973	184.4		1981	201.00
1972	183.5		1982	203.39
1971	183.5		1983	205.65
1970	181.5	183.81	1984	207.77
1969	181.5		1985	209.76
1968	181.5		1986	211.63
1967	178.5		1987	213.39
1966	170.0		1988	215.03
1965	169.8	173.07	1989	216.57
1964	161.3		1990	218.02
1963	153.4		1991	219.37
1962	146.8		1992	220.64
1961	146.8		1993	221.83
1960	146.8	154.16	1994	222.94
1959	146.8		1995	223.97
1958	146.8		1996	224.94
1957	146.8		1997	225.95
1956	128.1		1998	226.70
1955	125.6	123.28	1999	227.94
1954	125.6		2000	228.22
1953	125.6		2001	228.91

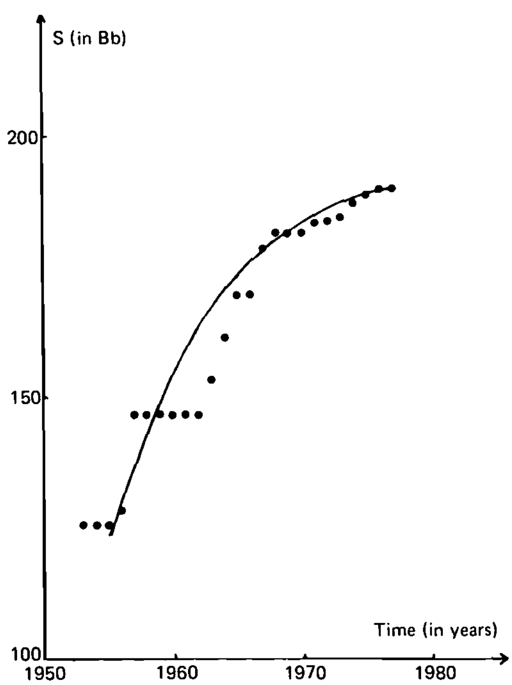

Figure A7.3. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: Saudi Arabia.

Table A7.10

Kuwait, Bahrain, and Neutral Zone:
1977 Estimate of Ultimate Recovery, S (Bb).*

End of Year	Kuwait	Bahrain	Neutral Zone
1977	91.7	1.0	9.1
1976	91.7	1.0	9.1
1975	91.7	1.0	9.1
1974	91.7	1.0	9.1
1973	91.7	1.0	9.1
1972	91.7	1.0	9.1
1971	91.7	1.0	9.1
1970	91.7	1.0	9.1
1969	91.7	1.0	9.1
1968	91.7	1.0	9.1
1967	91.7	1.0	9.1
1966	91.7	1.0	8.8
1965	91.7	1.0	8.8
1964	91.7	1.0	8.8
1963	91.7	1.0	8.8
1962	91.7	1.0	8.6
1961	90.6	1.0	8.6
1960	90.6	1.0	1.7
1959	90.6	1.0	1.7
1958	88.5	1.0	1.7
1957	88.5	1.0	1.7
1956	88.5	1.0	1.7
1955	84.3	1.0	1.7
1954	76.1	1.0	1.7

*The current ultimate recovery Q for the years 1977 to 2001 is constant and equal to 91.7 Bb for Kuwait, 1.0 Bb for Bahrain, and 9.1 Bb for the Neutral Zone.

Table A7.11
Estimates of Ultimate Recovery: Iraq (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	55.2	55.20	1977	55.20
1976	55.2		1978	56.85
1975	54.2	54.62	1979	58.41
1974	54.2		1980	59.90
1973	53.2		1981	61.31
1972	52.2		1982	62.64
1971	52.2		1983	63.91
1970	51.4	51.23	1984	65.10
1969	51.4		1985	66.23
1968	49.4	48.92	1986	67.29
1967	49.2		1987	68.29
1966	49.2		1988	69.24
1965	49.2		1989	70.13
1964	49.2		1990	70.97
1963	49.2		1991	71.76
1962	49.2		1992	72.50
1961	49.2		1993	73.19
1960	48.7		1994	73.84
1959	48.7		1995	74.46
1958	48.7	48.92	1996	75.03
1957	48.7		1997	75.57
1956	48.2		1998	76.07
1955	48.2	44.12	1999	76.55
1954	48.2		2000	76.99
1953	46.2		2001	77.40
1952	24.1			
1951	24.1			

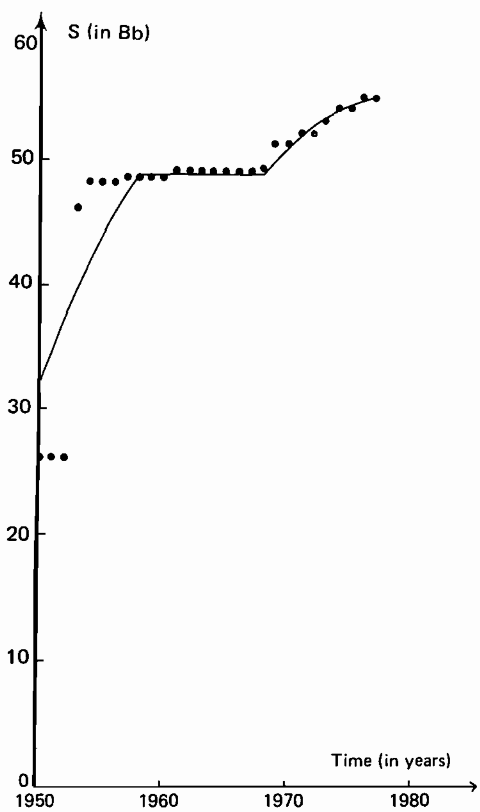

Figure A7.4. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: Iraq.

Table A7.12
Estimates of Ultimate Recovery: United Arab Emirates (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	47.7	47.70	1977	47.70
1976	47.7		1978	49.12
1975	46.8	47.20	1979	50.48
1974	46.8	46.82	1980	51.76
1973	46.8	46.35	1981	52.98
1972	46.1		1982	54.13
1971	45.9		1983	55.22
1970	45.6	44.27	1984	56.25
1969	43.8	43.34	1985	57.23
1968	41.0		1986	58.15
1967	41.0		1987	59.01
1966	40.7		1988	59.83
1965	38.6	38.13	1989	60.60
1964	32.0	36.40	1990	61.32
1963	20.0		1991	62.00
1962	20.0		1992	62.64
1961	11.0		1993	63.25
1960	11.0	27.32	1994	63.81
1959	11.0	24.42	1995	64.34
1958	11.0		1996	64.83
1957	6.0		1997	65.30
1956	6.0		1998	65.74
1955	6.0	9.66	1999	66.14
1954	6.0	5.05	2000	66.53
			2001	66.88

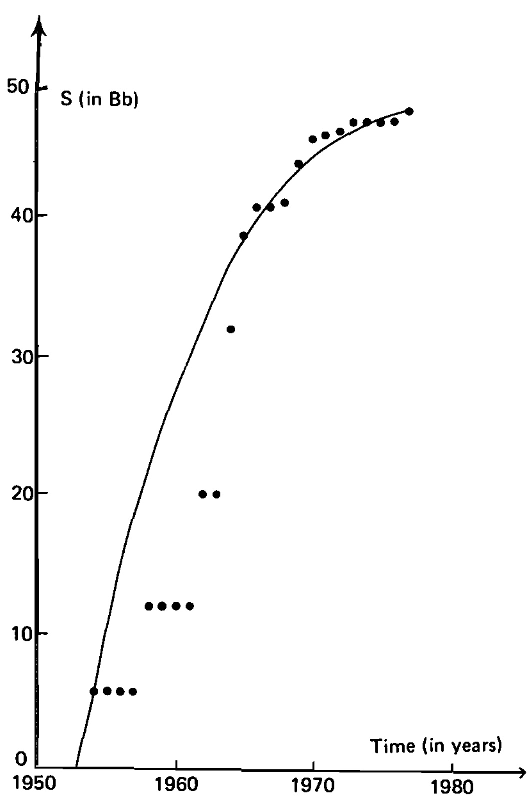

Figure A7.5. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: United Arab Emirates.

Table A7.13
Estimates of Ultimate Recovery: North Africa (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	55.5	55.50	1977	55.50
1976	54.4		1978	57.36
1975	54.3	54.67	1979	59.14
1974	53.0		1980	60.82
1973	51.3	53.33	1981	62.42
1972	50.7		1982	63.94
1971	50.6	51.41	1983	65.38
1970	49.9		1984	66.74
1969	49.9	48.82	1985	68.03
1968	47.9		1986	69.25
1967	46.7	45.44	1987	70.39
1966	42.3		1988	71.48
1965	40.4	41.16	1989	72.50
1964	38.2		1990	73.46
1963	37.7	35.83	1991	74.36
1962	37.5		1992	75.21
1961	36.4	29.27	1993	76.01
1960	22.2		1994	76.76
1959	20.8	21.28	1995	77.47
1958	11.1		1996	78.13
1957	11.0	11.61	1997	78.75
1956	10.8		1998	79.33
1955	0.8		1999	79.87
			2000	80.38
			2001	80.86

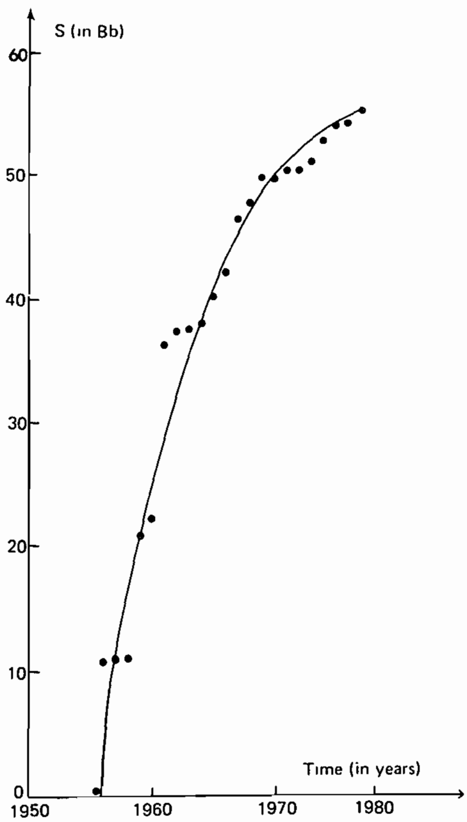

Figure A7.6. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: North Africa.

Table A7.14
Estimates of Ultimate Recovery: Libyan Arab Jamahiriya (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	35.6	35.6	1977	35.60
1976	34.9		1978	36.79
1975	34.8	35.1	1979	37.93
1974	33.7		1980	39.01
1973	33.2		1981	40.04
1972	33.2		1982	41.01
1971	33.2	33.7	1983	41.93
1970	33.2		1984	42.81
1969	33.2		1985	43.63
1968	31.4	31.3	1986	44.41
1967	30.2		1987	45.15
1966	26.7		1988	45.84
1965	25.5		1989	46.50
1964	24.1	26.4	1990	47.12
1963	24.1		1991	47.69
1962	24.0		1992	48.24
1961	23.6		1993	48.75
1960	10.6	18.8	1994	49.23
1959	9.4		1995	49.69
1958	0.1		1996	50.11
1957		10.7	1997	50.51
			1998	50.88
			1999	51.23
			2000	51.56
			2001	51.86

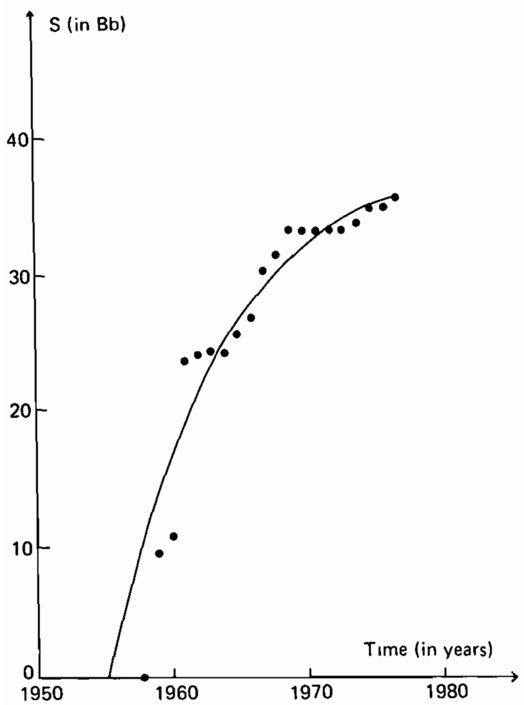

Figure A7.7. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: Libyan Arab Jamahiriya.

Table A7.15

Estimates of Ultimate Recovery: Algeria (Bb).

End of Year	1977 Estimate of Ultimate Recovery, S	Calculated Values of S	End of Year	Current Ultimate Recovery, Q
1977	15.2	15.2	1977	15.20
1976	15.2		1978	15.60
1975	15.2	15.1	1979	15.90
1974	15.0		1980	16.25
1973	14.7		1981	16.57
1972	14.7		1982	16.86
1971	14.7		1983	17.14
1970	14.3	14.5	1984	17.40
1969	14.3		1985	17.65
1968	14.1		1986	17.89
1967	14.1		1987	18.11
1966	13.2		1988	18.31
1965	12.7	13.1	1989	18.51
1964	12.4		1990	18.69
1963	12.4		1991	18.86
1962	12.3		1992	19.02
1961	11.6		1993	19.17
1960	10.8	10.6	1994	19.32
1959	10.6		1995	19.45
1958	10.2		1996	19.57
1957	10.2		1997	19.69
1956	10.0	7.4	1998	19.80
			1999	19.90
			2000	20.00
			2001	20.08

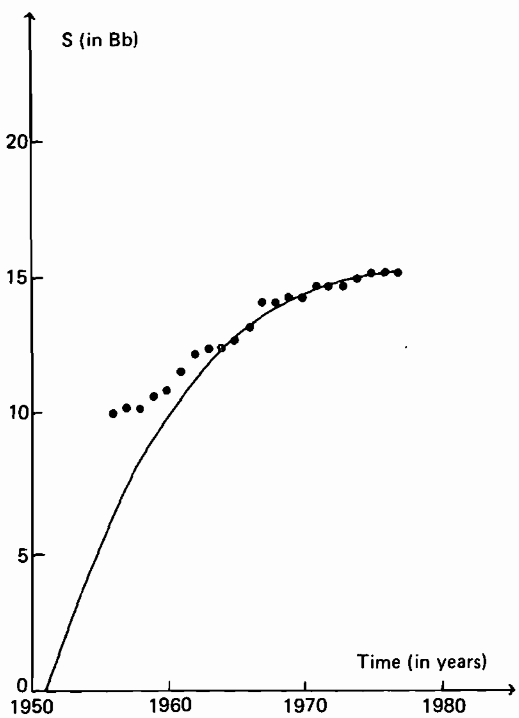

Figure A7.8. Observations and theoretical fit of the 1977 estimate of ultimate recovery, S: Algeria.

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APPENDIX EIGHT
PAST ECONOMIC PERFORMANCE AND GROWTH PROSPECTS OF THE ARAB WORLD, 1960 - 2000

PAST PERFORMANCE

The Statistics Unit of ECWA has compiled, for the purposes of this study, estimates of the real gross domestic product (GDP) of each of the 21 Arab countries, expressed at constant prices of 1970 and in 1970 US dollars [10]. In converting country data at current prices into constant price estimates, the so-called "physical method approach" was used, which consisted of deflating, for each country and for each sector, value added at current prices by a price index computed for that country and that sector.

The country estimates cover the years 1960 to 1977 and are broken down by kind of economic activity. Table A8.1 shows estimates of GDP by country, while Table A8.2 presents estimates of the aggregate GDP of the Arab world by kind of economic activity.

An examination of Table A8.2 calls for the following remarks.

During the 1960-1977 period the contribution of crude oil production to Arab value added in the mining and quarrying sector (denoted MQ) averaged 97 percent.[1] Thus, MQ can be safely taken as a proxy for the crude oil component of GDP. This is confirmed by the high correlation obtained in the following simple linear regression based on data for 1960-1977, where the dependent variable MQ is in million 1970 dollars (from Table A8.2), the explanatory variable P is Arab crude oil production in billion barrels (from Appendix 3, Table A3.2) and $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom:

$$MQ = 712.1 + 1.540\,P \qquad (\bar{R}^2 = 0.994). \tag{1}$$

During 1960-1973, the noncrude oil component of Arab GDP (represented by GDP less than MQ) rose by an average of 5.7 percent per annum. The big rise in real income produced by the oil price increases of 1973-1974 led to a rapid growth in those components of the noncrude oil economy where lack of demand had been a serious restraining factor and supply constraints were not too restrictive: this meant primarily increases in construction (20.3 percent annual growth between 1973 and 1977 as against 7.1 percent in 1960-1973) and services (11.0 percent as against 6.6 percent), with agriculture little affected (2.4 percent as against 2.5 percent) and manufacturing showing relatively modest gains (8.2 percent as against 6.2 percent) because capacity was limited and demand could be met by imports. As a result, Arab GDP generated outside the crude oil sector rose in real terms by 10.1 percent per annum between 1973 and 1977.

The contrast between the big rise in distribution (11.5 per annum) and the relatively slow growth in the physical production of consumer goods (4.9 percent per annum) between 1973 and 1977 can be easily explained by the fact that the distributors could handle imports and were not much affected by lack of capacity, whereas the growth in the

[1] Production of phosphate ore in Morocco and Jordan and of iron ore in Mauritania has been responsible for the bulk of the remainder.

agriculture and manufacturing sectors was held down by supply-side considerations.

GROWTH PROSPECTS

Looking to the position from 1977 onwards, the expected slow growth of the world economy will probably have only a limited impact on Arab countries, because oil represents so large a part of their exports; besides, growth in Arab oil output is assumed to be held down as a matter of policy (see Chapter 4).

The agricultural sector in the Arab world is likely to grow faster than in the past but still less rapidly than overall GDP. An average annual growth rate of about 4 percent would represent a plausible trend up to 2000.

The industrial sector may be expected to do rather better than in 1973-1977, because the rate at which new capacity becomes available should rise, and there will be more gains from the overcoming of initial teething troubles on new-type plants recently completed. Assuming that the terms of trade (which depend largely on real oil prices) do not deteriorate, growth in this sector is likely to be more rapid than that of overall GDP. It is assumed that industry would grow at 12 percent between 1977 and 1985, 10 percent between 1985 and 1990, and 9 percent between 1990 and 2000.

The construction sector will most probably grow at a slower pace than in 1973-1977 (more than 20 percent), but its performance is likely to remain relatively high, at least in the coming years when the oil-rich countries may be expected to continue to spend a lot of government revenues on construction of hospitals, schools, housing, etc. Consequently, it is assumed that this sector would grow at 10 percent between 1977 and 1985, 8 percent between 1985 and 1990, and 6 percent between 1990 and 2000.

The services sector, like construction, is likely to grow less rapidly than in 1973-1977 but a little faster than overall GDP, on the grounds that the terms of trade would not deteriorate. It is assumed that this sector would grow at 9 percent between 1977 and 1985, 8 percent between 1985 and 1990, and 6 percent between 1990 and 2000.

In sum, Arab GDP generated outside the crude oil sector would, thus, grow at 9 percent between 1977 and 1985, 8 percent between 1985 and 1990, and 6.5 percent between 1990 and 2000.

As to the mining and quarrying sector, its future performance is estimated here using equation (1) above, on the basis of the magnitudes of crude oil production projected in Chapter 4. This implies an average growth of about 2 percent in this sector between 1977 and 1990 and 1 percent between 1990 and 2000.

Based on all the above, Tables A8.3 and A8.4 summarize the major findings of this short analysis.

It is worth noting, in conclusion, that the projected growth rates shown in the last row of Table A8.3 are those of Arab GDP *at constant 1970 prices*. Had a year other than 1970 been chosen as the price base, say 1977, the projected growth rates would have been different. In fact, prices in the mining and quarrying sector have increased between 1970 and 1977 much faster than in the other sectors, so as to give that component a greater share of GDP at 1977 prices than at 1970 prices, and the slow growth projected for mining and quarrying would have resulted in overall GDP increasing less rapidly. A rough calculation suggests that Arab GDP at constant 1977 prices would grow at an average rate close to 6 percent between 1977 and 2000, as against 7 percent for GDP at 1970 prices. It is, therefore, important to bear in mind that projected GDP magnitudes (Table A8.4) are more meaningful than projected GDP growth rates (Table A8.3) in this exercise.

Table A8.1

GDP of Arab Countries, 1960-1977 (million US dollars of 1970, at constant 1970 prices).*

Country	1960	1961	1962	1963	1964	1965	1966	1967	1968
Algeria	3,559	3,125	2,468	3,117	3,161	3,312	3,213	3,538	3,912
Bahrain	106	108	111	114	123	137	148	167	179
Democratic Yemen	296	321	333	353	363	386	338	258	229
Djibouti	28	36	44	50	50	52	54	60	63
Egypt	4,367	4,539	4,968	5,441	5,680	5,993	6,046	6,087	6,395
Iraq	1,842	2,055	2,171	2,114	2,338	2,659	2,689	2,637	3,046
Jordan	315	389	383	408	466	512	516	382	461
Kuwait	1,625	1,673	1,867	1,978	2,142	2,249	2,416	2,553	2,676
Lebanon	930	974	1,026	1,084	1,146	1,249	1,364	1,252	1,410
LAJ	485	538	715	980	1,398	1,787	2,119	2,339	3,142
Mauritania	91	106	105	104	138	151	157	168	184
Morocco	2,249	2,197	2,456	2,597	2,626	2,674	2,637	2,809	3,157
Oman	44	45	45	56	56	64	64	98	195
Qatar	132	136	143	146	166	180	212	234	269
Saudi Arabia	1,633	1,871	2,113	2,241	2,454	2,751	3,069	3,345	3,645
Somalia	201	211	218	227	206	197	221	232	238
Sudan	1,376	1,472	1,612	1,638	1,662	1,668	1,638	1,654	1,873
SAR	924	1,005	1,245	1,253	1,360	1,389	1,360	1,412	1,469
Tunisia	925	953	959	1,061	1,102	1,143	1,181	1,181	1,290
UAE	99	111	151	170	275	348	418	460	568
Yemen	263	271	279	286	284	281	290	288	292
Arab World	21,432	21,864	23,221	25,229	27,084	29,023	30,161	31,088	34,605

Country	1969	1970	1971	1972	1973	1974	1975	1976	1977
Algeria	4,241	4,512	4,405	4,955	5,451	5,929	6,394	6,944	7,609
Bahrain	188	210	217	221	230	277	293	375	413
Democratic Yemen	217	214	214	221	223	243	240	273	294
Djibouti	67	71	79	84	90	90	94	102	90
Egypt	6,906	7,236	7,633	8,057	8,419	8,544	9,209	9,946	10,911
Iraq	3,168	3,265	3,431	3,548	3,914	4,407	5,209	6,286	6,574
Jordan	522	490	509	534	531	587	617	701	754
Kuwait	2,800	2,710	3,165	3,252	3,261	3,111	2,965	3,270	3,472
Lebanon	1,447	1,490	1,636	1,801	1,742	1,823	1,477	555	1,027
LAJ	3,565	3,722	3,906	4,074	4,489	5,001	5,431	6,371	6,887
Mauritania	181	202	205	213	188	210	220	232	227
Morocco	3,187	3,351	3,526	3,683	3,744	4,106	4,197	4,645	4,966
Oman	244	260	280	287	303	419	503	563	579
Qatar	345	350	439	511	615	730	717	944	981
Saudi Arabia	3,948	4,400	5,102	6,033	7,127	7,764	8,170	9,261	10,376
Somalia	207	221	239	257	269	275	285	294	303
Sudan	1,794	2,186	2,360	2,284	2,261	2,374	2,476	2,598	2,723
SAR	1,714	1,740	2,016	2,180	2,144	2,558	3,009	3,165	3,231
Tunisia	1,350	1,444	1,602	1,886	1,896	2,070	2,283	2,464	2,568
UAE	727	730	912	1,011	1,302	1,609	1,880	2,359	2,531
Yemen	281	290	327	346	361	387	424	447	487
Arab World	37,155	39,202	42,205	45,401	48,578	52,548	56,111	61,814	67,030

*Country data may not add up to the Arab world total because of statistical discrepancies included in country GDP's.

Table A8.2

GDP of the Arab World by Kind of Economic Activity, 1960-1977 (million US dollars of 1970, at constant 1970 prices).*

Year	Agriculture, Forestry, & Fishing	Mining & Quarrying	Manufacturing	Electricity, Gas, & Water	Construction	Wholesale & Retail Trade	Transport & Communication	Other	GDP at Producer's Value
1960	4,814	3,028	2,122	303	1,175	3,365	1,293	5,322	21,432
1961	4,662	3,171	2,270	325	1,157	3,410	1,370	5,499	21,864
1962	5,312	3,522	2,416	350	1,111	3,197	1,474	5,839	23,221
1963	5,363	4,261	2,558	357	1,270	3,506	1,534	6,380	25,229
1964	5,425	5,045	2,626	387	1,321	3,765	1,655	6,860	27,084
1965	5,608	5,607	2,853	420	1,482	3,977	1,760	7,316	29,023
1966	5,089	6,295	2,969	455	1,509	4,232	1,758	7,854	30,161
1967	5,425	6,562	2,988	490	1,577	4,307	1,586	8,153	31,088
1968	5,843	7,812	3,249	536	1,815	4,788	1,794	8,768	34,605
1969	5,994	8,597	3,578	598	1,907	5,173	1,956	9,352	37,155
1970	5,891	9,044	3,863	631	1,945	5,931	2,105	9,792	39,202
1971	6,210	9,495	4,035	693	2,163	6,290	2,400	10,919	42,205
1972	6,840	9,958	4,307	765	2,447	6,711	2,681	11,692	45,401
1973	6,585	11,210	4,826	868	2,859	6,966	3,034	12,230	48,578
1974	7,331	10,721	5,175	946	3,467	7,656	3,540	13,712	52,548
1975	7,457	10,489	5,291	1,022	4,159	8,590	4,034	15,069	56,111
1976	7,514	11,643	5,989	1,190	5,085	9,499	4,499	16,395	61,814
1977	7,329	11,843	6,640	1,417	5,940	10,766	4,942	18,153	67,030

*Not including statistical discrepancies.

Table A8.3

Past and Projected Growth Rates in the Arab World, 1960-2000 (average annual percentage).

	1960-1973	1973-1977	1977-1985	1985-1990	1990-2000	1977-2000
Agriculture	2.5	2.4	4.0	4.0	4.0	4.0
Industry	6.4	8.9	12.0	10.0	9.0	10.2
Construction	7.1	20.3	10.0	8.0	6.0	7.8
Services	6.6	11.0	9.0	8.0	6.0	7.4
Noncrude Oil GDP	5.7	10.1	9.0	8.0	6.5	7.7
Mining and Quarrying	11.0	1.9	1.9	2.0	1.0	1.5
Arab GDP	6.6	8.4	8.0	7.4	6.1	7.0

Table A8.4

Projected GDP of the Arab World by Kind of Economic Activity, 1977-2000 (billion US dollars of 1970, at constant 1970 prices).

	1977	1985	1990	2000
Agriculture	7.3	10.0	12.2	18.0
Industry	8.1	20.0	32.2	75.9
Construction	5.9	12.6	18.5	33.0
Services	33.9	67.4	98.9	176.3
Noncrude Oil GDP	55.2	110.0	161.8	303.2
Mining and Quarrying	11.8	13.7	15.1	16.6
Arab GDP	67.0	123.7	176.9	319.8

APPENDIX NINE
ILLUSTRATIVE GEOGRAPHICAL BREAKDOWN OF THE ARAB WORLD'S PROJECTED ENERGY BALANCES, 1985, 1990, AND 2000

This study has been designed to produce forecasts of the energy balances of the Arab world as a whole. Thus, a breakdown by country of the regional results presented in Chapter 8 goes, strictly speaking, beyond the methodological scope of the projections. However, a close examination of the way each of the 19 exogenous variables in the energy balance model is projected (see Table 3.1 and pages following) reveals that 12 out of them (PGL, ECP, EPP, PNG, XNG, ENG, PPE, ELG, ESF, XEL, PSF, and TSF) are estimated by adding up country forecasts.

The remaining seven exogenous variables (PCP, CPP, REF, RCP, RNG, REL, and BNK) are projected in the study on a regional basis: PCP is estimated in Chapter 4 using an aggregative crude oil production policy for Arab-producing countries, while the other six variables are projected in Chapter 5 using a separate model mainly based on a common policy for the export of refined products from the Arab world taken as a whole.

Table A9.1

Geographical Breakdown of the Arab World by Countries or Groups of Countries.

Arab Africa
- Algeria
- Egypt
- Libyan Arab Jamahiriya
- Other Arab Africa (Djibouti, Mauritania, Morocco, Somalia, Sudan, and Tunisia)

Arab Middle East
- Iraq
- Kuwait
- Saudi Arabia
- United Arab Emirates
- Other Arabian Peninsula (Bahrain, Democratic Yemen, Oman, Qatar, and Yemen)
- Other Arab Middle East (Jordan, Lebanon, and Syrian Arab Republic)

For the sake of illustration, a geographical breakdown of the regional energy balances of 1985, 1990, and 2000 presented in Chapter 8 is attempted here. For this purpose, the Arab world is divided into ten countries or group of countries, as presented in Table A9.1 below.

The breakdown is described below.

Country forecasts are easily derived from the information included in Chapters 6, 7, and 8, for the 12 exogenous variables PGL, PNG and XNG; PPE, ELG, ESF, ECP, EPP, ENG and XEL; and PSF and TSF.

PCP as projected in Chapter 4 is apportioned among individual countries on the basis of their crude reserve position and prospects, announced or probable production policies, and national goals and aspirations. For instance, countries with large populations, ambitious development programmes, and/or financial needs are assumed to produce near sustainable capacity, while others are projected to observe conservationist production policies.

CPP as estimated in Chapter 5 is distributed among countries or groupings in direct proportion to the corresponding projected GDPs, the latter being derived in line with the findings of Appendix 8.

REF as projected in Chapter 5 is disaggregated on the basis of prospective country developments in domestic demand, refinery capacity and output mix, the export of products and "reconstituted" crude, and the use of outside refineries on commission.

RCP, RNG, and REL as estimated in Chapter 5 are broken down in direct proportion to country/grouping refinery output, with upward or downward revisions in some cases (e.g., for countries that do not produce gas, for countries with more sophisticated refineries than others, etc.).

BNK as projected in Chapter 5 is allocated on the basis of past trends, oil export possibilities, and growth prospects of each country/grouping.

The remaining 19 variables are then determined endogenously, using the 19 identity relationships inherent to the structure of the energy balance model (Table 3.1).

The results are presented in Tables A9.2 to A9.13.

The limitations of this method are obvious. The results, therefore, are only illustrative and should be considered with caution. This is particularly true for the breakdown of PCP, CPP, REF, and BNK, as well as the variables determined through any of these.

Table A9.2

Arab Africa*: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	2.2	212.8	53.1	81.3	4.5		353.9
Net energy exports (–)	1.2	–115.4	–73.0	–60.7		–	–247.9
International bunkers (–)	–	–	–4.5				–4.5
Total primary energy requirements	3.4	97.4	–24.4	20.6	4.5	–	101.5
Electricity generation	–0.6	–	–11.0	–6.2	–4.5	6.2	–16.1
Refineries		–97.4	93.8	–1.9		–0.3	–5.8
Gross final consumption	2.8	–	58.4	12.5		5.9	79.6
				1990			
Primary energy production	3	223	56	133	9		424
Net energy exports (–)	1	–97	–76	–100		–	–272
International bunkers (–)	–	–	–6				–6
Total primary energy requirements	4	126	–26	33	9	–	146
Electricity generation	–1	–	–14	–10	–9	10	–24
Refineries		–126	122	–3		–	–7
Gross final consumption	3	–	82	20		10	115
				2000			
Primary energy production	4	233	62	189	18		506
Net energy exports (–)	1	–55	–63	–114		–	–231
International bunkers (–)	–	–	–9				–9
Total primary energy requirements	5	178	–10	75	18	–	266
Electricity generation	–1	–	–22	–22	–18	21	–42
Refineries		–178	172	–5		–	–11
Gross final consumption	4	–	140	48		21	213

*Algeria, Djibouti, Egypt, Libyan Arab Jamahiriya, Mauritania, Morocco, Somalia, Sudan, and Tunisia.

Table A9.3

Algeria: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.1	50.6	46.7	69.2	0.1		166.7
Net energy exports (–)	0.1	−26.1	−57.6	−57.3		–	−140.9
International bunkers (–)	–	–	−0.6				−0.6
Total primary energy requirements	0.2	24.5	−11.5	11.9	0.1	–	25.2
Electricity generation	–	–	–	−4.4	−0.1	1.3	−3.2
Refineries		−24.5	23.6	−0.8		−0.1	−1.8
Gross final consumption	0.2	–	12.1	6.7		1.2	20.2
				1990			
Primary energy production	–	46	49	119	1		215
Net energy exports (–)	–	−11	−65	−97		–	−173
International bunkers (–)	–	–	−1				−1
Total primary energy requirements	–	35	−17	22	1	–	41
Electricity generation	–	–	–	−7	−1	3	−5
Refineries		−35	34	−1		–	−2
Gross final consumption	–	–	17	14		3	34
				2000			
Primary energy production	–	41	53	166	1		261
Net energy exports (–)	–	−6	−56	−111		–	−173
International bunkers (–)	–	–	−2				−2
Total primary energy requirements	–	35	−5	55	1	–	86
Electricity generation	–	–	–	−17	−1	6	−12
Refineries		−35	34	−1		–	−2
Gross final consumption	–	–	29	37		6	72

Table A9.4

Egypt: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.4	45.6	0.5	3.6	2.8		52.9
Net energy exports (–)	1.0	–19.6	–2.5	–		–	–21.1
International bunkers (–)	–	–	–0.8				–0.8
Total primary energy requirements	1.4	26.0	–2.8	3.6	2.8	–	31.0
Electricity generation	–	–	–6.0	–1.1	–2.8	2.8	–7.1
Refineries		–26.0	25.0	–0.6		–0.1	–1.7
Gross final consumption	1.4	–	16.2	1.9		2.7	22.2
				1990			
Primary energy production	1	45	1	4	5		56
Net energy exports (–)	1	–17	2	–		–	–14
International bunkers (–)	–	–	–1				–1
Total primary energy requirements	2	28	2	4	5	–	41
Electricity generation	–	–	–7	–2	–5	4	–10
Refineries		–28	27	–1		–	–2
Gross final consumption	2	–	22	1		4	29
				2000			
Primary energy production	1	45	1	6	11		64
Net energy exports (–)	1	–6	6	–		–	1
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	2	39	5	6	11	–	63
Electricity generation	–	–	–10	–3	–11	9	–15
Refineries		–39	38	–1		–	–2
Gross final consumption	2	–	33	2		9	46

Table A9.5

Libyan Arab Jamahiriya: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	–	111.5	5.8	7.6	–		124.9
Net energy exports (–)	–	–91.1	–8.6	–3.4		–	–103.1
International bunkers (–)	–	–	–1.3				–1.3
Total primary energy requirements	–	20.4	–4.1	4.2	–	–	20.5
Electricity generation	–	–	–2.9	–	–	0.8	–2.1
Refineries		–20.4	19.7	–0.4		–	–1.1
Gross final consumption	–	–	12.7	3.8		0.8	17.3
				1990			
Primary energy production	–	122	6	9	1		138
Net energy exports (–)	–	–94	–8	–3		–	–105
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	–	28	–4	6	1	–	31
Electricity generation	–	–	–4	–	–1	1	–4
Refineries		–28	27	–1		–	–2
Gross final consumption	–	–	19	5		1	25
				2000			
Primary energy production	–	137	7	12	1		157
Net energy exports (–)	–	–88	–8	–3		–	–99
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	–	49	–3	9	1	–	56
Electricity generation	–	–	–7	–	–1	2	–6
Refineries		–49	47	–2		–	–4
Gross final consumption	–	–	37	7		2	46

Table A9.6

Other Arab Africa*: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	1.7	5.1	0.1	0.9	1.6		9.4
Net energy exports (–)	0.1	21.4	–4.3	–		–	17.2
International bunkers (–)	–	–	–1.8				–1.8
Total primary energy requirements	1.8	26.5	–6.0	0.9	1.6	–	24.8
Electricity generation	–0.6	–	–2.1	–0.7	–1.6	1.3	–3.7
Refineries		–26.5	25.5	–0.1		–0.1	–1.2
Gross final consumption	1.2	–	17.4	0.1		1.2	19.9
				1990			
Primary energy production	2	10	–	1	2		15
Net energy exports (–)	–	25	–5	–		–	20
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	2	35	–7	1	2	–	33
Electricity generation	–1	–	–3	–1	–2	2	–5
Refineries		–35	34	–		–	–1
Gross final consumption	1	–	24	–		2	27
				2000			
Primary energy production	3	10	1	5	5		24
Net energy exports (–)	–	45	–5	–		–	40
International bunkers (–)	–	–	–3				–3
Total primary energy requirements	3	55	–7	5	5	–	61
Electricity generation	–1	–	–5	–2	–5	4	–9
Refineries		–55	53	–1		–	–3
Gross final consumption	2	–	41	2		4	49

*Djibouti, Mauritania, Morocco, Somalia, Sudan, and Tunisia.

Table A9.7

Arab Middle East*: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.2	959.7	47.0	70.1	2.7		1,079.7
Net energy exports (–)	–	–795.9	–110.3	–2.9		–	–909.1
International bunkers (–)	–	–	–24.2				–24.2
Total primary energy requirements	0.2	163.8	–87.5	67.2	2.7	–	146.4
Electricity generation	–	–2.0	–11.9	–15.7	–2.7	8.9	–23.4
Refineries		–161.8	155.9	–3.8		–0.2	–9.9
Gross final consumption	0.2	–	56.5	47.7		8.7	113.1
				1990			
Primary energy production	–	1,072	51	106	7		1,236
Net energy exports (–)	–	–796	–181	–13		–	–990
International bunkers (–)	–	–	–27				–27
Total primary energy requirements	–	276	–157	93	7	–	219
Electricity generation	–	–3	–18	–28	–7	16	–40
Refineries		–273	262	–9		–1	–21
Gross final consumption	–	–	87	56		15	158
				2000			
Primary energy production	–	1,198	76	193	14		1,481
Net energy exports (–)	–	–647	–369	–33		–	–1,049
International bunkers (–)	–	–	–31				–31
Total primary energy requirements	–	551	–324	160	14	–	401
Electricity generation	–	–4	–23	–70	–14	35	–76
Refineries		–547	522	–23		–2	–50
Gross final consumption	–	–	175	67		33	275

*Bahrain, Democratic Yemen, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, and Yemen.

Table A9.8

Iraq: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.1	202.7	2.3	7.5	1.5		214.1
Net energy exports (–)	–	–183.0	–4.9	–		–	–187.9
International bunkers (–)	–	–	–1.9				–1.9
Total primary energy requirements	0.1	19.7	–4.5	7.5	1.5	–	24.3
Electricity generation	–	–0.4	–1.0	–3.1	–1.5	1.8	–4.2
Refineries		–19.3	18.6	–0.5		–	–1.2
Gross final consumption	0.1	–	13.1	3.9		1.8	18.9
				1990			
Primary energy production	–	229	3	11	3		246
Net energy exports (–)	–	–199	–6	–		–	–205
International bunkers (–)	–	–	–3				–3
Total primary energy requirements	–	30	–6	11	3	–	38
Electricity generation	–	–1	–1	–5	–3	3	–7
Refineries		–29	28	–1		–	–2
Gross final consumption	–	–	21	5		3	29
				2000			
Primary energy production	–	269	6	20	6		301
Net energy exports (–)	–	–215	–7	–		–	–222
International bunkers (–)	–	–	–4				–4
Total primary energy requirements	–	54	–5	20	6	–	75
Electricity generation	–	–1	–1	–12	–6	7	–13
Refineries		–53	51	–2		–	–4
Gross final consumption	–	–	45	6		7	58

Table A9.9

Kuwait: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	–	111.5	6.2	12.8	–		130.5
Net energy exports (–)	–	−77.7	−27.0	–		−0.1	−104.8
International bunkers (–)	–	–	−4.1				−4.1
Total primary energy requirements	–	33.8	−24.9	12.8	–	−0.1	21.6
Electricity generation	–	–	−2.8	−0.8	–	1.4	−2.2
Refineries		−33.8	32.5	−0.9		−0.1	−2.3
Gross final consumption	–	–	4.8	11.1		1.2	17.1
				1990			
Primary energy production	–	111	7	14	–		132
Net energy exports (–)	–	−54	−46	–		–	−100
International bunkers (–)	–	–	−4				−4
Total primary energy requirements	–	57	−43	14	–	–	28
Electricity generation	–	–	−5	–	–	2	−3
Refineries		−57	54	−2		–	−5
Gross final consumption	–	–	6	12		2	20
				2000			
Primary energy production	–	111	7	17	2		137
Net energy exports (–)	–	−28	−66	–		–	−94
International bunkers (–)	–	–	−4				−4
Total primary energy requirements	–	83	−63	17	2	–	39
Electricity generation	–	–	−6	–	−2	3	−5
Refineries		−83	79	−4		−1	−9
Gross final consumption	–	–	10	13		2	25

Table A9.10

Saudi Arabia: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	–	486.4	26.7	23.2	–		536.3
Net energy exports (–)	–	–428.6	–43.9	–		–	–472.5
International bunkers (–)	–	–	–13.2				–13.2
Total primary energy requirements	–	57.8	–30.4	23.2	–	–	50.6
Electricity generation	–	–1.4	–3.3	–7.0	–	2.7	–9.0
Refineries		–56.4	54.3	–1.4		–0.1	–3.6
Gross final consumption	–	–	20.6	14.8		2.6	38.0
				1990			
Primary energy production	–	568	27	36	–		631
Net energy exports (–)	–	–463	–75	–		–	–538
International bunkers (–)	–	–	–14				–14
Total primary energy requirements	–	105	–62	36	–	–	79
Electricity generation	–	–2	–4	–14	–	5	–15
Refineries		–103	99	–4		–1	–9
Gross final consumption	–	–	33	18		4	55
				2000			
Primary energy production	–	629	40	83	1		753
Net energy exports (–)	–	–347	–219	–12		–	–578
International bunkers (–)	–	–	–16				–16
Total primary energy requirements	–	282	–195	71	1	–	159
Electricity generation	–	–2	–2	–40	–1	13	–32
Refineries		–280	267	–12		–1	–26
Gross final consumption	–	–	70	19		12	101

Table A9.11

United Arab Emirates: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	—	106.4	8.1	12.4	—		126.9
Net energy exports (—)	—	−90.5	−16.9	−2.9		—	−110.3
International bunkers (—)	—	—	−1.2				−1.2
Total primary energy requirements	—	15.9	−10.0	9.5	—	—	15.4
Electricity generation	—	—	−0.6	−2.4	—	0.8	−2.2
Refineries		−15.9	15.3	−0.4		—	−1.0
Gross final consumption	—	—	4.7	6.7		0.8	12.2
				1990			
Primary energy production	—	117	10	20	—		147
Net energy exports (—)	—	−87	−30	−7		—	−124
International bunkers (—)	—	—	−1				−1
Total primary energy requirements	—	30	−21	13	—	—	22
Electricity generation	—	—	−1	−4	—	1	−4
Refineries		−30	29	−1		—	−2
Gross final consumption	—	—	7	8		1	16
				2000			
Primary energy production	—	127	16	32	—		175
Net energy exports (—)	—	−67	−56	−12		—	−135
International bunkers (—)	—	—	−2				−2
Total primary energy requirements	—	60	−42	20	—	—	38
Electricity generation	—	—	−1	−8	—	2	−7
Refineries		−60	57	−3		—	−6
Gross final consumption	—	—	14	9		2	25

Table A9.12

Other Arabian Peninsula*: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	–	43.6	3.6	13.4	–		64.6
Net energy exports (–)	–	–28.0	–14.9	–		–	–42.9
International bunkers (–)	–	–	–2.2				–2.2
Total primary energy requirements	–	19.6	–13.5	13.4	–	–	19.5
Electricity generation	–	–0.2	–0.5	–2.2	–	0.9	–2.0
Refineries		–19.4	18.7	–0.4		–	–1.1
Gross final consumption	–	–	4.7	10.8		0.9	16.4
				1990			
Primary energy production	–	42	4	24	–		70
Net energy exports (–)	–	–13	–21	–6		–	–40
International bunkers (–)	–	–	–3				–3
Total primary energy requirements	–	29	–20	18	–	–	27
Electricity generation	–	–	–1	–4	–	2	–3
Refineries		–29	28	–1		–	–2
Gross final consumption	–	–	7	13		2	22
				2000			
Primary energy production	–	57	7	37	–		101
Net energy exports (–)	–	–28	–17	–9		–	–54
International bunkers (–)	–	–	–3				–3
Total primary energy requirements	–	29	–13	28	–	–	44
Electricity generation	–	–	–2	–7	–	4	–5
Refineries		–29	28	–1		–	–2
Gross final consumption	–	–	13	20		4	37

*Bahrain, Democratic Yemen, Oman, Qatar, and Yemen.

Table A9.13

Other Arab Middle East*: Projected Energy Balances, 1985, 1990, and 2000 (Mtoe).

	Solid Fuels	Crude Petroleum	Petroleum Products	Natural Gas	Primary Electricity	Electricity	Total
				1985			
Primary energy production	0.1	5.1	0.1	0.8	1.2		7.3
Net energy exports (–)	–	11.9	–2.7	–		0.1	9.3
International bunkers (–)	–	–	–1.6				–1.6
Total primary energy requirements	0.1	17.0	–4.2	0.8	1.2	0.1	15.0
Electricity generation	–	–	–3.7	–0.2	–1.2	1.3	–3.8
Refineries		–17.0	16.5	–0.2		–	–0.7
Gross final consumption	0.1	–	8.6	0.4		1.4	10.5
				1990			
Primary energy production	–	5	–	1	4		10
Net energy exports (–)	–	20	–3	–		–	17
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	–	25	–5	1	4	–	25
Electricity generation	–	–	–6	–1	–4	3	–8
Refineries		–25	24	–		–	–1
Gross final consumption	–	–	13	–		3	16
				2000			
Primary energy production	–	5	–	4	5		14
Net energy exports (–)	–	38	–4	–		–	34
International bunkers (–)	–	–	–2				–2
Total primary energy requirements	–	43	–6	4	5	–	46
Electricity generation	–	–1	–11	–3	–5	6	–14
Refineries		–42	40	–1		–	–3
Gross final consumption	–	–	23	–		6	29

*Jordan, Lebanon, and Syrian Arab Republic.

APPENDIX TEN

INDEX OF RECENT OIL AND ENERGY SUPPLY AND DEMAND PROJECTIONS

The index is in chronological order within each geographical grouping.

	Title and/or Source	*Date of Issue*	*Time Horizon*
WORLD (by major countries/groupings)			
1.	"Energy Prospects," by Department of Energy (Advisory Council on Energy Conservation), United Kingdom (UK)	June 1976	1980, 1985, 1990
2.	"National Energy Outlook 1980-1990," by Shell Oil Company USA	September 1976	1980, 1985, 1990
3.	"World Energy Outlook," by OECD Secretariat	January 1977	1980, 1985
4.	Caltex Petroleum Company USA	February 1977	2000
5.	"World Energy Outlook," by Exxon Corporation	March 1977	1980, 1985, 1990
6.	"The International Energy Situation Outlook to 1985," by US Central Intelligence Agency (CIA)	April 1977	1980, 1985
7.	"Energy: Global Prospects 1985-2000," by Workshop on Alternative Energy Strategies (WAES)	May 1977	1985, 2000
8.	"Project Interdependence: US and World Energy Outlook through 1990," by Congressional Research Service, Library of US Congress	July 1977	1980, 1985, 1990
9.	US International Trade Commission	August 1977	1980, 1985
10.	Irving Trust Company	December 1977	1980, 1985
11.	World Energy Conference (various reports)	1977–1978	1985, 2000, 2020
12.	Brookings Institution	March 1978	1980, 1985
13.	"World Energy Outlook," by Exxon Corporation	April 1978	1980, 1985, 1990
14.	"Outlook for World Oil into the Twenty-First Century," by Petroleum Industry Research Foundation Incorporated (PIRINC)	May 1978	1980, 1985, 1990
15.	"Forecast of Energy Supply and Demand in the Non-Communist World," by T. Ushijima, Mitsubishi Oil Comapny Limited	June 1978	1985, 1990
16.	Saudi Arabian Minister of Petroleum	June 1978	1980 to 1987

	Title and/or Source	Date of Issue	Time Horizon
17.	"Technical Analysis of the International Oil Market," prepared by Petroleum Economics Limited for US Department of Energy	June 1978	1980, 1985, 1990
18.	Standard Oil of California	October 1978	1990
19.	"Steam Coal: Prospects to 2000," by OECD Secretariat	November 1978	1985, 1990, 2000
20.	"Facing the Future: Mastering the Probable and Managing the Unpredictable," by Interfutures Project, OECD	1979	2000
21.	"A Comparison of Energy Projections to 1985," by J.R. Brodman and R.E. Hamilton, IEA	January 1979	1985
22.	"Petroleum in World Energy Balances to the Year 2000," by J. Roorda, Shell Oil Company USA	September 1979	1980, 1985, 1990, 2000
23.	US Department of Energy (Energy Information Administration)	September 1979	1980, 1985, 1990, 1995
24.	"The World Oil Market in the Years Ahead," by US CIA	September 1979	1980, 1982
25.	"The World Oil Situation and OPEC: The Razor's Edge," by Michael F. Thiel, Consultant	September 1979	1980, 1985, 1990
26.	"World Producing Capacity of Hydrocarbons," by F.R. Parra, Petroleos de Venezuela	Septmeber 1979	
27.	"Power Reactors in Member States," IAEA	October 1979	1980, 1985, 1990
28.	"World Energy Balances: Looking to 2020," by E. Ruttley, Secretary General of World Energy Conference	October 1979	1980 to 2020
29.	US Congressional Budget Office	November 1979	1985, 1990
30.	"World Energy Outlook," by Exxon Corporation	December 1979	1990, 2000
31.	"Energy in a Finite World: A Global Energy Systems Analysis," by IIASA Energy Systems Programme	1980	2000, 2030
32.	Shell International	February 1980	1980 to 1984

OECD or IEA (by countries/groupings)

1.	Economic Models Limited	November 1977	1981, 1986
2.	"Energy Policies and Programmes of IEA Countries: 1977 Review," by OECD/IEA Secretariat	June 1978	1980, 1985, 1990
3.	"Energy Policies and Programmes of IEA Countries: 1978 Review," by OECD/IEA Secretariat	June 1979	1985, 1990
4.	"Petroleum Supply/Demand Balances: 'Notional Gaps' and Policy Consequences," by D. Sternlight, Atlantic Richfield Company	September 1979	1980, 1982, 1985
5.	IEA	December 1979	1980, 1985

Appendix Ten

Title and/or Source	Date of Issue	Time Horizon
USA		
1. Continental Oil Company USA	November 1976	1990
2. "US Energy Outlook," by Exxon Company USA	January 1977	1980, 1990
3. "National Energy Outlook 1977," by US Federal Energy Administration	March 1977	1985, 1990
4. "National Energy Plan," Fact Sheet released by the White House	April 1977	1985
5. Mobil Oil Corporation	April 1977	1990
6. PIRINC	October 1977	1980, 1985, 1990
7. General Accounting Office, US Congress	October 1977	1985
8. US Department of Energy (preliminary version of Market Oriented Programme Planning Study)	January 1978	1985, 2000
9. "US Energy Outlook," by Exxon Company USA	January 1978	1980, 1985, 1990
10. "National Energy Outlook 1980-1990," by Shell Oil Company USA	February 1978	1980, 1985, 1990
11. US Department of Energy (Energy Information Administration)	May 1978	1985, 1990
12. Arthur D. Little	1979	1985, 1990
13. Asiatic Petroleum (Shell)	1979	1980, 1981
14. Gulf Oil USA	1979	1990
15. Shell Oil Company USA	1979	1980, 1985, 1990
16. "US Energy Outlook," by Exxon Company USA	January 1979	1980, 1985, 1990
17. "US Energy Outlook," by Exxon Company USA	January 1980	1980, 1990, 2000
18. "US Oil Discovery and Production: The Projections of M. King Hubbert," by E. Renshaw and P.F. Renshaw, State University of New York at Albany, USA	February 1980	1980 to 2000
CANADA		
1. Texaco Canada	August 1976	1980, 1985, 1990
2. Gulf Oil Canada	November 1976	1985, 1990
3. Canadian National Energy Board	June 1977	1985, 1995
4. Imperial Oil Canada	October 1977	1995
JAPAN		
1. Japanese Ministry of International Trade and Industry (MITI)	March 1977	1980
2. Japanese Overall Energy Council	June 1977	1985, 1990
3. MITI	April 1978	1980 to 1982
4. MITI	April 1979	1980 to 1983
5. MITI	August 1979	1995

Title and/or Source	*Date of Issue*	*Time Horizon*
UNITED KINGDOM		
1. UK Department of Energy	February 1978	1985, 2000
2. UK Department of Energy	April 1978	1980 to 1982
3. UK Department of Energy	July 1979	1980 to 1983
4. Wood Mackenzie and Company	January 1980	1980 to 1982
EUROPEAN ECONOMIC COMMUNITY (EEC)		
1. Commission of the European Communities (CEC)	February 1976	1980, 1985
WESTERN EUROPE		
1. UK National Institute of Economic and Social Research	November 1978	1980, 1985
OPEC COUNTRIES		
1. "OPEC in the Medium-Term," by W.J. Levy, Consultants	September 1976	1980
2. IEA	April 1977	1985
3. "Energy Crisis in 1985?," by Robert Mabro, St. Anthony's College, Oxford, UK	February 1978	1985
4. "Estimating Energy Demand in OPEC Countries," by Adnan Al-Janabi, OPEC Secretariat	April 1979	1985, 1990
5. "Domestic Energy Requirements in OPEC Member Countries," by S.A.R. Kadhim and A. Al-Janabi, OPEC Secretariat	October 1979	1980 to 2000
NON-OPEC DEVELOPING COUNTRIES		
1. "Energy and Petroleum in Non-OPEC Developing Countries, 1974-1980," by the World Bank	February 1976	1980
2. World Bank	1979	1980, 1985
3. Mexico Special Report, by *Oil and Gas Journal*	August 1979	1980 to 1983
CPE's OF EUROPE		
1. United Nations Economic Commission for Europe (ECE)	May 1978	1980, 1990

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By P.H. Frankel and W.L. Newton, Petroleum Economics Limited, London. Special Paper Presented to the Tenth World Petroleum Congress (9–14 September 1979, Bucharest). Heyden & Son Limited, London, 1979.

[13] *Utilization of Natural Gas Resources in the Middle East* (in French).
By J.P. Kandalaft. Saint Joseph University, Beirut, 1974.

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By Hisham Khatib. Published in *Energy in the Arab World: Proceedings of the First Arab Energy Conference (4–8 March 1979, Abu Dhabi, U.A.E.),* Volume 3. Arab Fund for Economic and Social Development, and Organization of Arab Petroleum Exporting Countries, Kuwait, 1980.

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[21] *Steam Coal: Prospects to 2000.*
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[22] *The OECD Observer.*
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[23] *The OECD Observer.*
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