RM-78-35

ON FOSSIL FUEL RESERVES AND RESOURCES

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June 1978

PREFACE

In relation to the tenth session of the World Energy Conference (WEC) in Istanbul, September 1977, the Conservation Commission sponsored three independent studies of three independent groups of world experts for assessing fossil resources and reserves of coal, oil, and gas, and their possible maximum production until 2020 (based on technical and economic considerations, but excluding political ones).

These three studies can be considered basic documents regarding energy resources and reserves. They represent the current thinking of the majority of experts in this field. Compared to our assessment studies on energy resources at IIASA, I would personally rank them as generally conservative (some of our figures are sensibly higher). As a consequence, the conclusions that can be drawn from these studies can also be considered conservative.

Although these executive summaries are not yet the final documents, they have been broadly distributed for comments. Because of their importance per se, and for our Energy Systems Program, particularly in relation to a 35 TW demand scenario for the world in the year 2030, I have thought it mandatory to summarize them very briefly, and to draw some synthetic conclusions for our own Resources Group in the Energy Systems Program.

ABSTRACT

This is a review of the major findings on coal, oil, and gas resources of the three independent groups of experts of the World Energy Commission which were presented to the Tenth World Energy Conference (WEC) at Istanbul in September 1977.

These aspects are put in perspective with the current thinking on fossil resources of the Resources Group of the Energy Systems Program, and are used to estimate some possible future fossil production in relation to a 35 TW demand scenario used in the Program.

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ON FOSSIL FUEL RESERVES AND RESOURCES*

INTRODUCTION

For the IIASA Energy Systems Program, whose particular interest is the transition from a fossil fuel based energy economy to a nonfossil fuel economy (nuclear, thermonuclear, solar, and geothermal energies, or an optimized mix of these), a reliable assessment of fossil reserves and resources is a basic requirement. Such evaluations are published irregularly and vary in value and credibility. Moreover, to aggregate them is especially difficult because of the different origins of the studies and the lack of common guidelines for establishing such evaluations.

For the tenth session of the World Energy Conference, held in Istanbul, September 19-23, 1978, the Conservation Commission of the World Energy Conference sponsored various studies on energy resources and demand. Three of them are of particular importance for our purpose:

- *Report on Coal Resources, 1985 to 2020, Executive Summary* by W. Peters and H.-D. Schilling;
- *Report on Oil Resources, 1985 to 2020, Executive Summary* by P. Desprairies;
- *The Future for World Natural Gas Supply, Final Draft Report* by W.T. McCormick, Jr. et al.

The quality of the groups of experts who performed these studies vouches for their importance. So it was thought most relevant to perform a detailed analysis of the three reports, to compare our own assessments with theirs, to understand their possible limitations, and to check very carefully how they could be used in our own Energy Program. Our special goal has been to see how, with minor modifications, they could be used as a basis for calculating the necessary inputs for the modeling efforts, pending our own inputs to be provided by the ENERDYM Model.

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* Quotations from the World Energy Conference (WEC) studies are in italics; any observations the author of the present paper has added to them are printed upright.

It was considered that this careful review work could be of interest to the members of the Energy Program in general, as well as to those dealing specifically with energy resources.

RESOURCES

Coal Resources

This study was performed by W. Peters and H. D. Schilling, with the assistance of W. Pickhardt, D. Wiegand, and R. Hildebrandt, from Bergbau-Forschung GMbH, Central Research and Development Institute of the Hard Coal Mining Industry of the Federal Republic of Germany [1].

Major Conclusions

Present-day geological world coal resources are estimated at more than 10,000 x 10^9 tons of coal equivalent (tce).... The world possesses abundant coal occurrences, which are rather well distributed over the various regions of the globe. One may also assume, in addition to currently estimated resources and reserves, that there is a considerable "potential behind the potential".

*These coal reserves currently estimated as technically and economically recoverable amount to c. 640 x 10^9 tce.... Since the potential of the coal reserves is so huge, and as we can expect the price of energy to rise on the market, it is very likely that the figure of 600 x 10^9 tce will double.**

According to the present planning of the coal producing countries and, also, additional estimates based primarily on present coal reserves, in the year 2020 a world coal production of 8.7 x 10^9 tce could be achieved, if the necessary actions are taken in time...and for a long time after that an increasing coal consumption could be a practical reality. This level of production would mean more than tripling today's world coal production and would require an average annual growth rate of 2.6%.

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* Before 2020.

In fact, the study seems reasonably optimistic concerning the resources and reserves--and the possibility to still increase both with a better geographic distribution--and less optimistic (even a little pessimistic) on the production capability because of a number of constraints: manpower (miners and engineers), infrastructure and transportation facilities, environmental problems, present insufficient development of potential markets, and long lead times. However, one should at the same time make it clear that these obstacles can be removed, provided that appropriate action is taken. These factors most generally affect developed countries*, and much less "newcomers" like Australia and South Africa, etc., who claimed at Istanbul that they had no practical limit on production, assuming they would get the long-term contracts needed to justify the investment.

It is also worth mentioning that until now most of the coal producing countries have planned the development of their production capacity on their own national demand, and not--or not yet!--on a possible increase of exportation, with average quotas between about 7 and 9 per cent of the production figures. This could change if a real coal importing market were progressively emerging. However, here is a problem underlined by the authors:

> *At present, the main problem seems to be that potential markets for coal are not yet sufficiently being developed, since other energy sources still are plentiful and offered at lower prices. This again leads to a lack of willingness on the part of potential investors to commit themselves to the development of coal.*
>
> *Considering the long lead times required for an extensive production and use of coal (and this includes policy decisions, investment commitments, coal mine development, transportation, etc.), one cannot merely rely on a future market which might be more favorable to coal.*
>
> *Action must be taken now, if the maximum use of the potential offered by coal is to be made. Therefore, appropriate policy decisions by governments and by coal consumers are imperative. These decisions should be aimed to enable potential coal consumers to commit themselves to long-term contracts. This, again, would enable and encourage potential investors to commit themselves in time, and without unacceptable risks, to the necessary development of coal.*

Clearly, this points to the necessity of a long-term (global) energy policy.

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* And especially a country like the FRG, which has uniquely reviewed downward its coal reserves. This can explain some of the latent pessimism of the authors.

Coming back to resources and reserves, which is our main item of interest, it is very important to note that the successive assessments by the World Energy Conference are rapidly increasing, as shown in Table 1.

Table 1. Comparison of WEC estimates of coal resources and reserves.

Year	Geological Resources 10^9tce	Technically and Economically Recoverable Reserves	Reserves Expressed as Percentage of Resources %
WEC 1974	8603	473	5.5
WEC 1975	9045	560	6.2
WEC 1977	10126	637	6.3

It is to be seen that both the geological resources and the reserves are following an upward trend, the jump in the resources between 1976 and the compilation of this report (August 1977), namely approximately 10^{12} tce, being a relatively large one. However, the geological resources and the technically and economically recoverable reserves are increasing nearly in the same ratio. One of the reasons for the higher figures is apparently to be found in the fact that many countries, following the changes in the energy economy situation in the years 1973/1974, have carried out a re-evaluation of their coal resources (especially of the resources).*

This process is far from ended. If we make new additions to resources and reserves in new coal countries, this supports one of the final statements of this study mentioned above, that it is very likely that the present figure of 600 x 10^9 tce will double (possibly in the coming decade).

* Reserves are even increasing slightly faster than the resources, according to the figures.

Table 2. Coal resources and reserves, broken down according to continents and countries
h.c. = hard coal (bituminous coal and anthracite)
b.c. = brown coal (subbituminous coal and lignite)

	Geological resources in 10^6 tce		Technically economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c
Total world	7 727 624	2 398 880	490 272	143 657
	10 126 504		636 929	

Continent: America

Country	Geological resources in 10^6 tce		Technically and economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c.
Argentina	--	384	--	100
Brazil	4 040	6 042	2 510	5 588
Canada	96 225	19 127	8 708	673
Chile	2 438	2 147	36	126
Columbia	7 633	685	397	46
Mexico	5 448	--	875	--
Peru	3 862	--	105	--
USA	1 190 000	1 380 398	113 230	64 358
Venezuela	1 630	--	978	--
Other countries	55	5	--	---
Total	1 311 331	1 408 788	126 839	70 891

Continent: Asia

Country	Geological resources in 10^6 tce		Technically and economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c.
Bangladesh	1 649	--	517	2
China (PR)	1 424 680	13 365	98 883	n.a.
India	55 575	1 224	33 345	335
Indonesia	573	3 150	80	1 350
Iran	385	--	193	--
Japan	8 583	58	1 000	6
North Korea	2 000	--	300	180
South Korea	921	--	386	--
Turkey	1 291	1 977	134	624
CSSR	3 993 000	867 000	82 900	27 000
Other countries	5 368	353	1 488	74
Total	5 494 025	887 127	219 226	29 591

Continent: **Europe**

Country	Geological resources in 10^6 tce		Technically and economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c.
Belgium	253	--	127	--
Bulgaria	34	2 599	24	2 179
Czechoslovakia	11 573	5 914	2 493	2 322
Fed. Rep. of Germany	230 300	16 500	23 919	10 500
France	2 325	42	427	11
German Democratic Rep.	200	9 200	100	7 560
Greece	--	895	--	400
Hungaria	714	2 839	225	725
Netherlands	2 900	--	1 430	--
Poland	121 000	3 000	20 800	990
Romania	590	1 287	50	363
Spain	1 786	512	322	215
UK	163 576	--	45 000	--
Yugoslavia	104	10 823	35	8 430
Other countries	309	130	58	57
Total	535 664	53 741	95 010	33 752

Continent: Australia and the Pacific South Sea

Country	Geological resources in 10^6 tce		Technically and economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c.
Australia	213 760	48 374	18 128	9 225
New Zealand	130	660	36	108
Other countries	--	--	--	--
Total	213 890	49 034	18 164	9 333

Continent: Africa

Country	Geological resources in 10^6 tce		Technically and economically recoverable reserves in 10^6 tce	
	h.c.	b.c.	h.c.	b.c.
Mozambique	400	--	80	--
Nigeria	--	180	--	90
Republic of Botswana	100 000	--	3 500	--
Republic of South Africa	57 566	--	26 903	--
Rhodesia	7 130	--	755	--
Swaziland	5 000	--	1 820	--
Zambia	228	--	5	--
Other countries	2 390	10	970	--
Total	172 714	190	34 033	90

Regarding the reality, or better, the reliability of the figures, the authors state:

> *Practically all the data given were accompanied with particulars on seam thickness and depth, which in part should be regarded as realistic under the view point of extractability. In many important countries, the data given on the resources are moreover clearly below the data that apply to occurrences, so that the figure of approximately 10,000 x 10^9 tce are within an order of magnitude that can be regarded as realistic for those resources that may some day be of economic interest for the population of the world. In view of the insufficient degree of exploration in many areas of the world, this figure might represent a lower limit. The conclusion can be drawn from these facts that the category comprising the present technically and economically recoverable reserves has still a further considerable enlargement potential.*

I just want to point out the fact that this already enormous 10,000 x 10^9 tce is probably a lower limit, and that if insufficient exploration (especially in many developing countries where exploration is nonexistent) gave way to more developed exploration, an improvement in the geographical distribution of the discovery of resources and reserves would result. This was the main conclusion of my own study at IIASA about two years ago (The Second Status Report [2]). Table 2 gives coal resources and reserves, broken down according to continents and countries.

Oil Resources

This study was prepared by Pierre Desprairies, Chairman of the Board, Institute Francais du Petrole. For the first time, as far as we know, Pierre Desprairies performed a Delphi analysis among various experts of the oil industry: 42 questionnaires were sent out, 29 replies were received, including 2 from public authorities, 18 from oil companies, 9 from independent experts and consultants; 20 receivers answered both series of questionnaires [3].

Major Conclusions*

> *(The figures given below and also the curves of maximum production derived from them are an evaluation of technical maxima in respect of what nature and available technology will make it possible to produce within the limit of a cost price increasing up to $20 (1976) per barrel in the year 2000, assuming that all conditions, and especially financial and political conditions, are favorable; they do not constitute production forecasts or predictions).*

* Unlike other studies on ultimate oil reserves, the Delphi study does not include past cumulative production; for comparisons, this has to be added (about 45 Gt).

Although they are different in nature, the oil study as well as the coal and gas studies have reservations about the possibility of achieving these maximum production capacities. However, in the present political and institutional climate prevailing almost everywhere in the Western world, this caution can unfortunately be applied to any kind of energy resource!

Ultimate recoverable resources worldwide remaining to be produced as of 1977, supposing that the present recovery rate of 25% is raised to 40% towards the end of the century, have been estimated by all the 28 experts as 260 Gt approximately, without counting deep offshore and the polar regions, which are still classified as unconventional petroleum; including these the estimate is 300 Gt.

If we limit our analysis of the replies to conventional petroleum (260 Gt) we find three opinions among the experts:

- *a majority opinion (2/3 of the replies) estimating ultimate recoverable resources at 240 Gt.*
- *an optimistic opinion (25% of replies) of 350 Gt* (I personally share this opinion).
- *a pessimistic opinion (10%) of 175 Gt.*

The 260 Gt were considered by the 28 experts as likely to be divided as follows: USA/Canada 11%; Western Europe 4.5%; USSR/China and the socialist countries 23%; Middle East and North Africa 42%; Africa south of the Sahara 4.5%; Latin America 9%; South and East Asia 6%.

The opinions on deep offshore and the polar regions were pessimistic or uncertain, with an average of 13% of the 300 Gt constituting ultimate resources.

In fact, had the same analysis been made one or two years ago, answers on deep offshore would probably have been more optimistic. They have, no doubt, been influenced by a few (less than 20) recent unsuccessful drillings*. However, my own opinion, and that of K. Emery [4] during the 1976 IIASA-UNITAR Conference, is that it is much too soon to come to any conclusion, whether

*Because of the very high cost of drilling and institutional difficulties (such as offshore Corsica in the Mediterranean) some of the very few deep-drilling ships are presently under-utilized or used in other areas (polymetalic nodules, for instance).

positive or negative. This was, in fact, confirmed in various discussions with some of the experts who answered the Delphi questionnaire, and who expressed their opinion that deep offshore petroleum, even with potentially huge reserves, would hardly play a role before the next century (i.e. in the time frame of the Delphi study), with a big uncertainty over its possible future costs. Some production specialists are more optimistic because of the impressive progress in deep offshore technology.

The polar zones pose problems both of production and transport. It hardly seems likely that they will be exploited before the end of this century. (This is why some experts quoted low figures, notwithstanding their future potential after 2000).

The importance attributed to the Middle East/North Africa zone (essentially the Middle East) is considerable... The reserves attributed to the socialist countries (23%) are considerable... It is important to continue offshore prospection, since 45% of world reserves are presumed to be there.

The experts are relatively optimistic about the future cost of petroleum production. More than half of the petroleum remaining to be exploited could be produced at costs less than present selling prices ($12 in 1976); a third could be produced at around present production costs (less than $5).

On the essential question of future discovery rate, most of the experts (2/3) are relatively optimistic for the near future (1985), with gross annual discoveries (new fields plus re-evaluation of old fields) of about 4 Gt per year, as compared with an average of 3 Gt between 1950 and 1975.

This is somewhat contradicted by the present leveling--or even slight decrease, according to some statistics--of world oil reserves; but this trend is heavily influenced by policy factors.

Of these gross discoveries, only 45% would constitute net discoveries of new deposits, with the other 55% accounted for by re-evaluation of old deposits, using enhanced recovery widely.

This re-evaluation process has not yet really started because enhanced recovery projects are still very scarce (apart from thermal recovery in California) and limited to a few countries.

The experts estimate that at the end of the century discoveries will not provide for the renewal of reserves at the present level of consumption (3 Gt).

Between now and 1985/90 it is estimated that prospection efforts will have to be at least doubled to obtain the same oil discoveries.

The reply is more optimistic on the costs of developing deposits at this same period (1985/90). Onshore, costs are scarcely likely to exceed present development costs in the USA ($5000/b/d). Development in the conventional marine zones will probably remain at about its present level for difficult offshore conditions ($10,000/b/d).

Enhanced recovery is expected to play an essential role towards the end of the century. At present, only 25-30% of petroleum in the ground is extracted; this figure will probably increase to 40% by about 2000: 45% in the industrialized countries, 42% in the socialist countries and 38% elsewhere.

Some experts (the French Petroleum Institute or M.L. Surguchev [5] during our 1976 IIASA UNITAR Conference) expect somewhat higher figures for enhanced recovery (in fact, the WEC report is not clear as to whether 40 percent will be the 2000 and maximum value, or whether this value will continue its slow increase after the year 2000). To stress the importance of such a value, let us say that each additional point above 40% to 750 Gt of oil in the ground (which gives 300 Gt at 40% recovery) adds 7.5 Gt, i.e. 2.5 times the present yearly production. Desprairies himself, in a later part of the report, refers to possible higher values of 45 to 50 percent.

The author further analyzes some of the main constraints that may limit the achievement of maximum production capacities, such as financial resources, actual rate of new deposit discovery and putting into operation methods of enhanced recovery, available skilled manpower, and, of even greater importance, political problems.

Among all the obstacles separating the technical possibilities of petroleum production from their actual realization, the most difficult to surmount is the failure to believe that they exist.

Before closing this section, we would like to compare the WEC Delphi results with other previous estimates and with our own preliminary estimates. In order that this may be better understood, we give in the Appendix some further explanation on oil reserves and resources, and the principal methods of estimating them.

Table 3. Estimates of ultimate world reserves of crude oil from conventional sources*.

Year	Source	10^9 bbl	10^9
1942	Pratt, Weeks, and Stebinger	600	82
1946	Duce	400	55
1946	Pogue	555	76
1948	Weeks	610	183
1949	Levorsen	1500	205
1949	Weeks	1010	138
1953	MacNaughton	1000	136
1956	Hubbert	1250	171
1958	Weeks	1500	205
1959	Weeks	2000	273
1965	Hendricks (USGS)	2480	338
1967	Ryman (Esso)	2090	285
1968	Shell	1800	246
1968	Weeks	2200	300
1969	Hubbert	1350-2100	184-286 (235)
1970	Moody (Mobil)	1800	246
1971	Warman (BP)	1200-2000	164-273 (218)
1971	Weeks	2290	312
1971	US National Petroleum Council	2670	364
1972	Linden	2950	402
1972	Weeks	3650	498
1972	Moody, Emerick (Mobil)	1800-1900	246-259 (252.5)
1975	Adams and Kirby (BP)	2000	273
1975	Sickler (Shell)	1190-1410**	162-192
1975	Moody (Mobil)	2030	277
1976	Klemme (Weeks)	1900	259

*Most of the original data were given in barrels (column 3) and have been converted into metric tons (column 4) at 7.33 bbl/t.

**Does not include socialist countries.

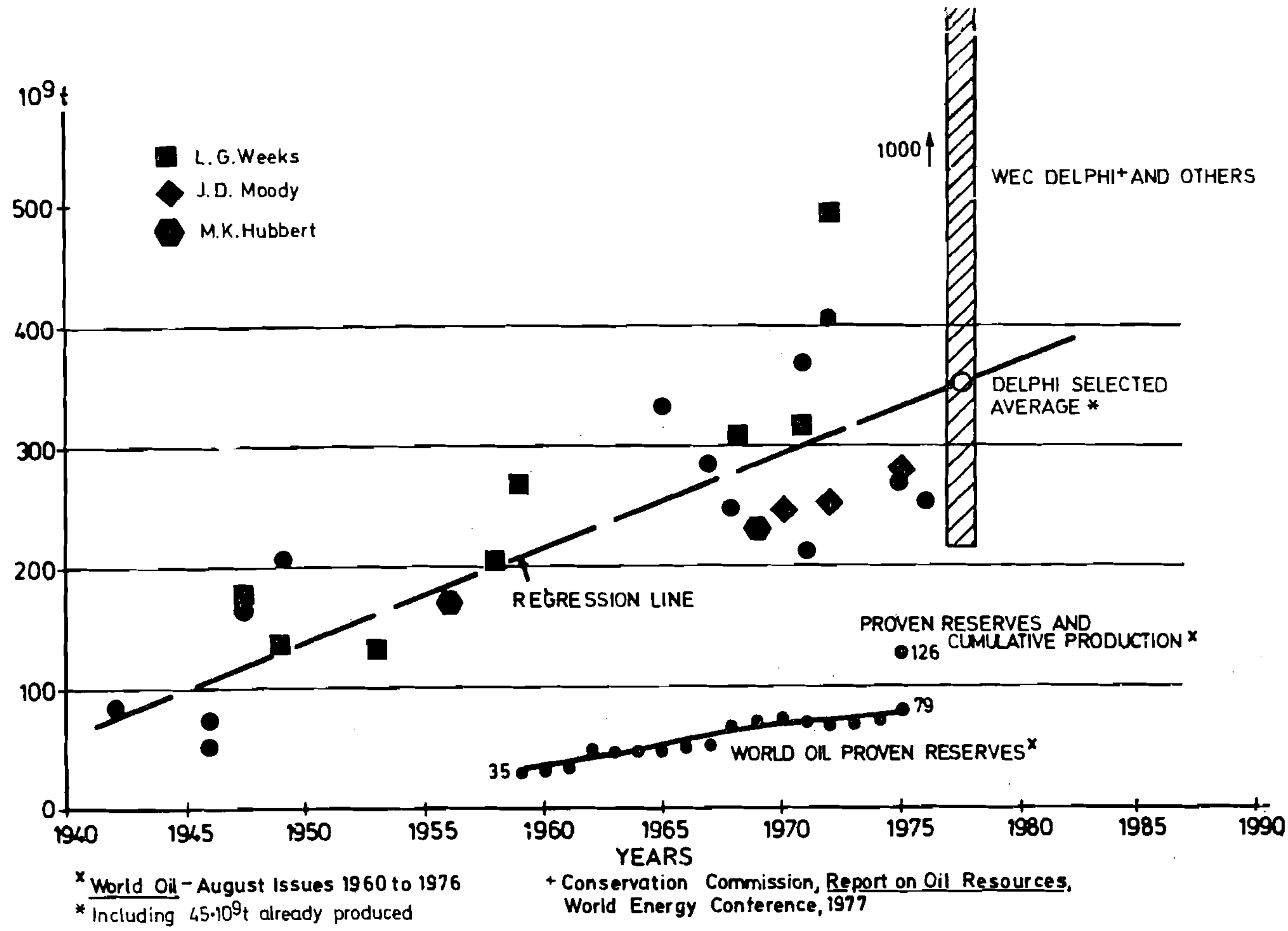

Figure 1. Estimates of world ultimate reserves of crude oil.

Table 3 gives estimates of ultimate world oil resources over a 35-year period, and Figure 1 shows the corresponding graphical representation (which does not include Sickler's estimates limited to the world excluding socialist countries). These estimates generally also include past production, proven reserves (with the uncertainties referred to in the Appendix), and expected "additions". Depending on the estimators, the expected additions may (or may not) include future discoveries, revisions due to changes in the recovery factor (controversial in recent years), offshore only to 200 m or up to 2000 m, Antarctica, etc. These assumptions are not always clearly specified, which makes the comparisons still more difficult. Because of its importance, the 1977 Delphi study for the Energy Conservation Commission of the World Energy Conference will be analyzed separately in the next section.

A few comments suffice for Table 3 which is well known. The 25 estimates (fewer than one per year) are in fact not independent. To these 25 estimates, Hubbert has contributed with two, Moody with three, and Weeks with eight (nine, if we include Klemme), which leaves some 15 "independent" estimates.

In the course of time, there has been a general trend--characterized by the regression line in Figure 1--towards increased estimates. This is apparent not only from independent estimators, but also from the successive upward revisions of Weeks' estimates. This trend has been extrapolated, with the support of a very interesting and controversial argumentation, by P. Odell [6] to predict that in the year 2000 the estimates could be about 4000 billion barrels, i.e. 570 billion tons (this estimate, however, is not given in Table 3 or in Figure 1).

It is interesting to observe that the dispersion of estimates was about the same between 1945 and 1950 as 25 years later, between 1970 and 1975. In fact, in 1975 to 1976, there was some "apparent convergence" around 250 to 280 billion tons of oil. This apparent convergence, however, did not stand up to the Delphi estimate, as shown in Figure 1, and as will be seen in more detail in the next section.

Because of its importance and its influence in oil industry circles and apparently also on other recent estimates, we give in Table 4 the 1975 estimate by John D. Moody [7]. The total expected recovery is given in the last, seventh, column (taking the list of countries as the first column), and is the sum of columns 2,3, 4 and 5. It is interesting to note that the total range of possible values given in column 6, which show the uncertainty of the estimates, is roughly a factor of ten for socialist countries (because of the lack of published data), but still a factor of three for the best explored country, the USA. Around the average value of 276.9 billion tons, the possible differences are about 20 percent, or more than 50 billion tons (more than 16 years of today's consumption), which is not trivial.

Moody pointed out in his paper that all his reserve and resource estimates were based on historical cost/profit relationships <u>prevailing before the 1973 oil embargo</u>. All reserve and resource figures are for recoverable crude oil only and exclude natural gas liquids (which may add another 10 to 20 percent). Estimates for proven and prospective <u>reserves</u> extend offshore to 200 m (600 ft), whereas the ultimate <u>resource</u> potential includes water depths up to 2000 m (6000 ft). However, due to recent development, Moody added,

> opinion of the potential of the world's deep ocean areas may well undergo significant reevaluation. And it is possible that the deeper ocean may be a potentially larger area than was estimated.*

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* This was written in 1975, a period slightly more optimistic in outlook than the present one, as mentioned above.

Table 4. Estimated ultimate world crude oil recovery, January 1, 1975 (in 10^9t) taken from Moody [7].

Countries	From Discovered Crude Oil		From Undiscovered Crude Oil Potential			
	Cumulative Production	Prospective & Proven Reserves*	Onshore	Offshore	Total Range On & Offshore	Total Recovery **
USSR, China, al.	6.8	17.5	37.5	3.4	9.5-95.5	65.2
United States	14.5	7.0	4.1	7.5	6.8-20.5	33.0
Canada	1.0	1.2	1.8	7.8	5.5-15.0	11.7
Middle East	10.6	59.3	17.7	2.7	10.2-38.2	90.5
Greater North Sea	0.1	3.0	-	6.1	2.7-10.9	9.3
Other Western Europe	0.3	0.3	0.4	1.2	0.9- 2.3	2.2
North Africa	1.9	5.4	3.6	1.0	2.0- 8.2	11.8
Gulf of Guinea	0.7	4.1	0.8	3.3	2.0- 6.8	8.9
Other Africa	-	-	0.3	0.8	0.4- 2.0	1.1
N.W. South America	4.9	3.4	3.1	1.2	2.7- 6.8	12.7
Other Latin America	1.2	1.9	2.2	4.7	3.1-13.0	10.0
Southeast Asia	1.2	3.1	0.5	3.8	2.5- 6.8	8.7
Other Far East	0.3	1.0	2.1	5.9	2.7-16.4	9.1
Antarctica	-	-	-	2.7	0.7- 6.8	2.7
Total	43.5	107.2	74.1	52.1	81.9-191.0	276.9

* Prospective reserves are also known as probable reserves.

** Total recovery is the source of columns 2,3,4, and 5 (taking the list of countries as column 1.)

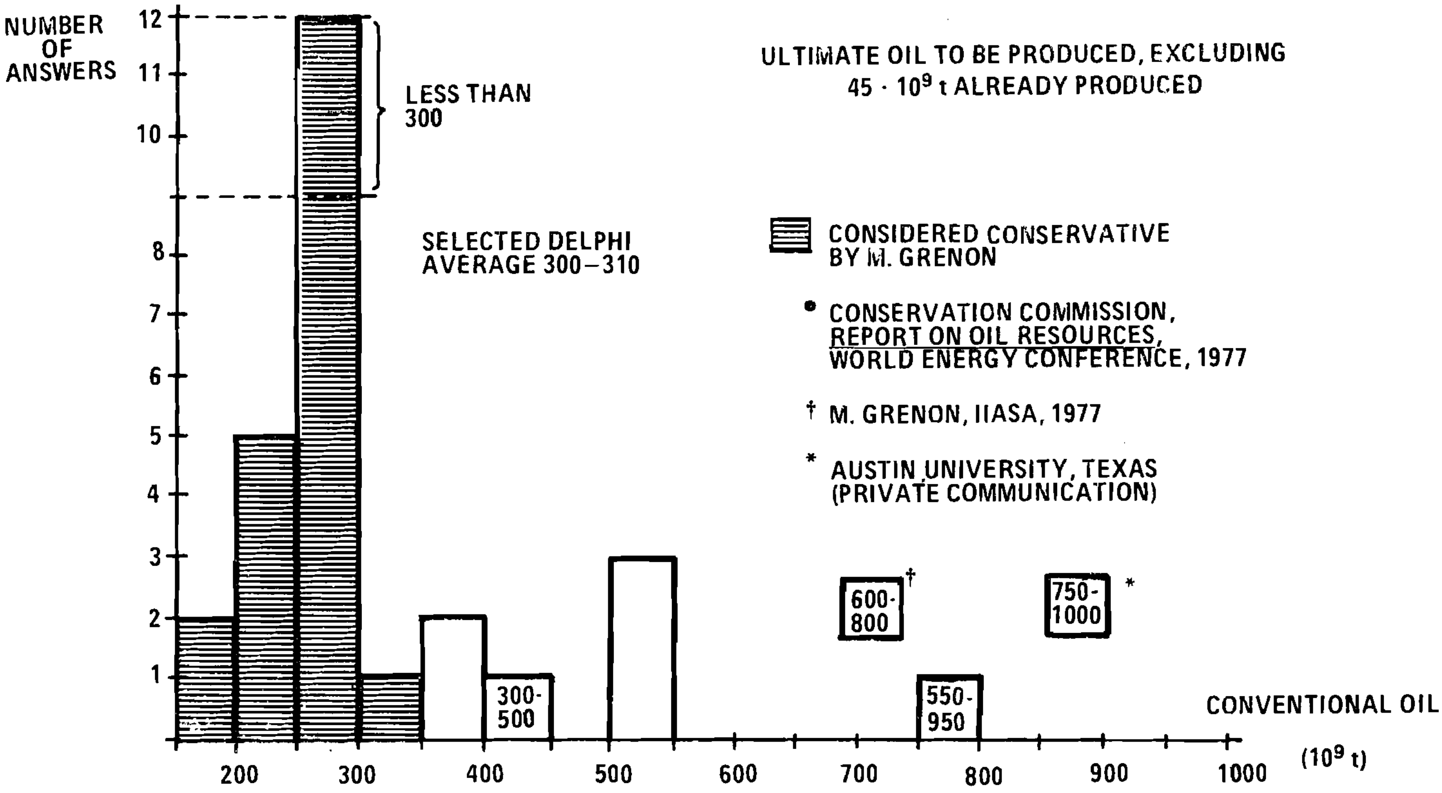


Figure 2. World Oil Resources Analysis of Delphi, after [3].

The 1977 World Energy Conference Delphi Study

Although the main conclusions of Desprairies from the Delphi study are given above, it is worthwhile analyzing in somewhat more detail the study itself, to contribute to our understanding of the ultimate reserves (resources) situation of oil.

The values chosen by Desprairies seem to privilege the answers in the middle of the range (200 to 300 Gt), and minimize or exclude the others, the two very low ones and the seven higher ones (26 percent of the answers!) If we take the average of all values, we find a total of 435.7 Gt, taking the lowest values of the two ranges given (300 Gt for range 300<<550, and 550 Gt for range 550<<950), and 478.6 Gt if we take medium values for the two ranges. This figure of about 478 Gt plus 45 Gt already produced, adds up to more than 250 Gt, about 50 percent more than the value selected. Three of the answers giving 500 Gt are less dispersed in detail than many other groups of answers. But there is, of course, some temptation to attach greater significance to the 12 answers in the narrow range of 250 to 300 Gt, which we could call "Moody's type" or "the petroleum industry's type", although four of them give only the total, less than 300 Gt, and no regional estimates.

The distribution of the answers is shown in graphical form in Figure 2. By way of comparison with Moody's data given in Table 4 the regional averages of the Delphi study are given in Table 5 for the two conditions, i.e. all the values are taken or only the values in the range 200 to less than 300 Gt (let us recall that cumulative production is not included). The regions are split up somewhat differently, but still permit the comparisons.

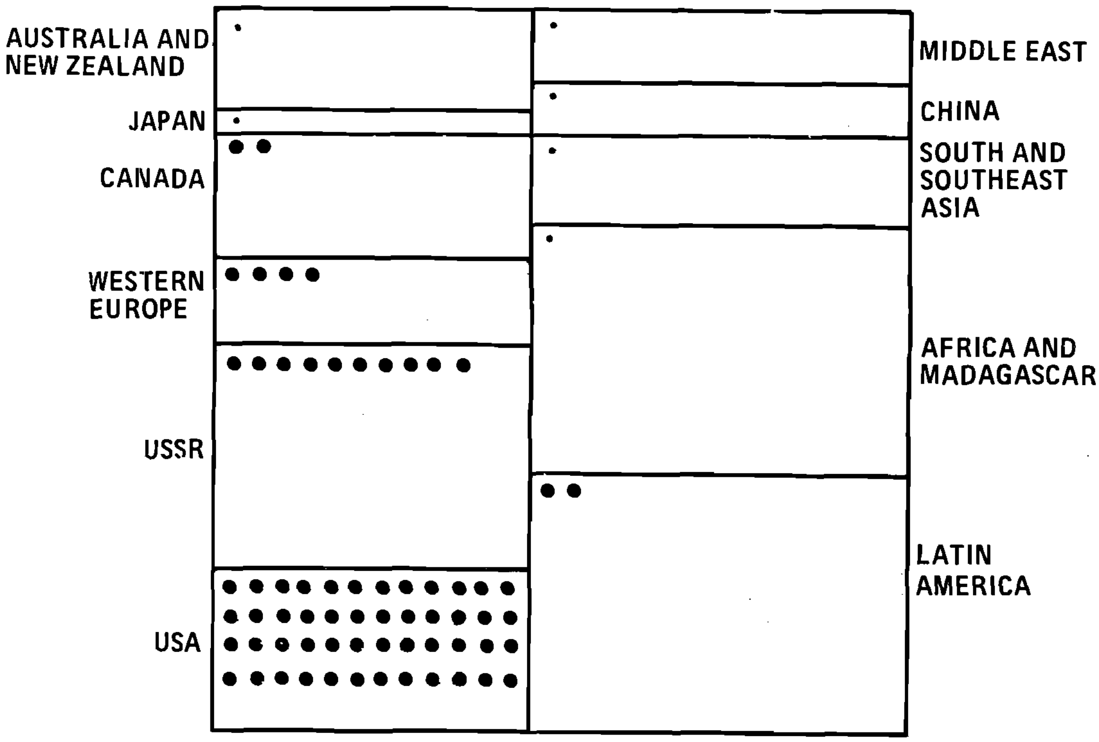
Table 5. Regional distribution of Delphi estimates.

	All Values			Values in Range 200-300 Gt*		
	Mini	Maxi	Average	Mini	Maxi	Average
Socialist Countries	27.3 -	96.3	59.4	40.3 -	83	54.5
USA and Canada	6.2 -	50	28.5	15.6 -	45	26.1
Middle East & North Africa	54.8 -	300	109.1	76 -	156	101.9
Africa South of Sahara	2.7 -	40	11.3	4 -	13.4	8.8
Western Europe	5 -	22	11.2	5 -	22	11.1
Latin America	7.9 -	55	22.9	12.5 -	36.9	20.9
East and South Asia (includes Japan, Australia & New Zealand	5.5 -	30	15.1	6 -	25	13.6
Deep Offshore and Polar Areas	0 -	230	38.7	0 -	50	21.2

* Of the 18 values in the range 200 to 300 Gt, four do not give details by regions.

At first sight, this table shows a very broad dispersion of expert estimates for the regions, although the various averages generally vary by less than ten percent if all values are considered or only those values in the narrower range of 200 to 300 Gt estimates. This is, however, not true for deep offshore and polar areas, for which experts have been particularly cautious, as explained above.

Curiously, the range of estimates is narrower for socialist countries, which do not publish any statistics, than for, say, the USA and Canada, by far the most explored countries in the world*. This can be due to the fact that most experts have no direct knowledge of the oil potential of socialist countries and are obliged to rely on a very few independent estimates.



Areas within the black bars represent, to scale, the extent of the petroleum prospective area (onshore + offshore to 200m water depth). Each full black circle represents 50,000 wells (exploratory + development) drilled in each partition of the chart. Numbers of wells smaller than 500,000 are represented approximately by segments of the full black circle.

Figure 3. Relative densities of oil drilling in various regions.

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* In his study, on the other hand, Moody had a very large range for socialist countries.

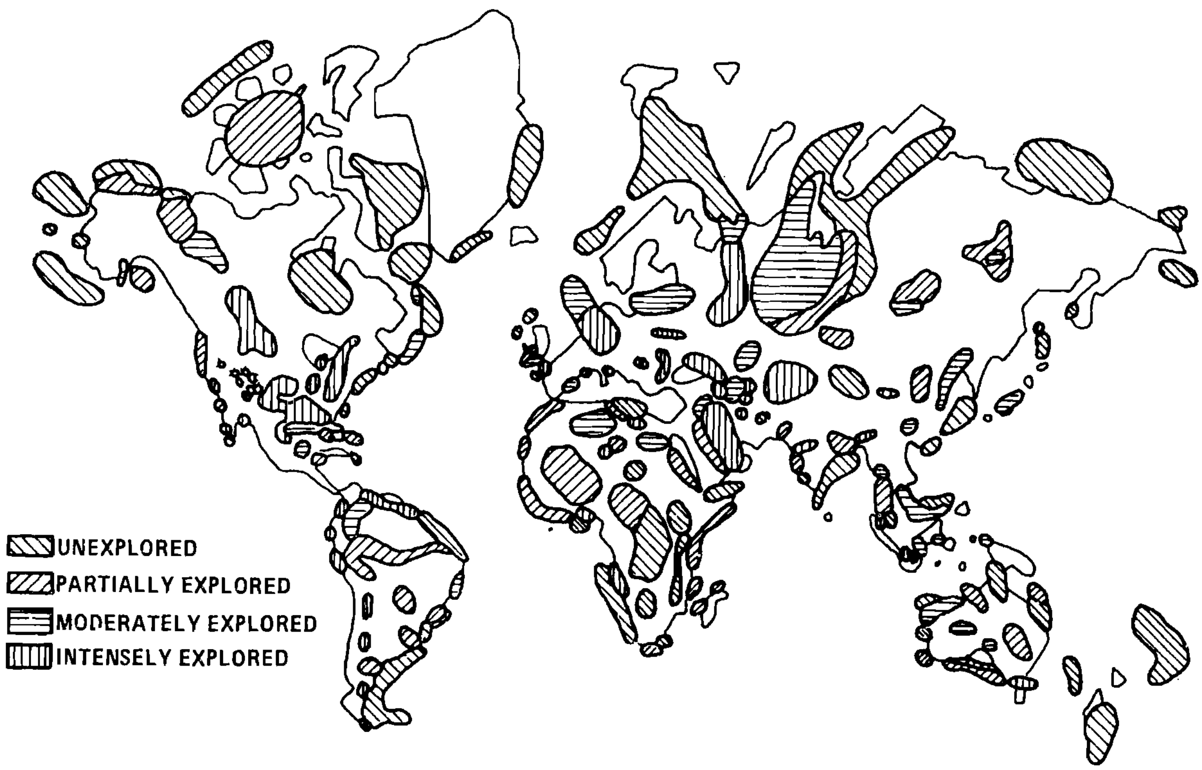

Figure 4. Oil Basins of the World Exploratory Status.

Also, USSR geology seems simpler, with fewer uncertain frontier areas. But anyhow, the wide dispersion of regional estimates invites us to handle them with much caution, and illustrates the actual relative poverty of our knowledge of the oil potential of the earth, even in a country that has been extensively drilled, such as the US. B.F. Grossling [8] and M.T. Halbouty [9] have illustrated dramatically that all the other regions have been more poorly explored than the US, as shown in Figures 3 and 4. Even for the US it is reported that most of the 2.5 million holes (stricto sensu intersecting an area of about 0.25 km^2 compared to the 6 million plus km^2 of sedimentary formations) were drilled to shallow depth, recording few, if any, of the precious geological data (during at least three-quarters of the oil industry's history) which are so badly needed for a better geological knowledge.

Another way to put this point is to raise the question: How much oil would have been discovered in the US if the drilling density had equalled only, say, that in Latin America?

Although we only have preliminary results, our own estimates of ultimate recoverable world oil reserves lie on the high side of the Delphi estimate, in the range of 600 to 800 Gt. In fact, extensive discussions with world oil experts--including some of those who answered the Delphi poll--show that there is less discrepancy than the raw figures would suggest, and that the main reason for such a difference can, on the whole, be attributed to the different interpretations of the frontier between conventional and unconventional oil and especially heavy crudes (which are generally not included in the Delphi estimates unless they are already being exploited, like many Californian deposits). Moreover, we are generally more optimistic about the future potential of little explored countries, most of them members of the less developed world [10].

Unconventional Oil

Since our IIASA-UNITAR Conference on "The Future Supply of Nature-made Petroleum and Gas" some interesting developments have occurred. Briefly stated, there has been no real breakthrough (or even outstanding progress) in chemical tertiary recovery, but, on the other hand, there has been a growing interest in thermal methods for the recovery of heavy crudes. The Canadian government has begun to act positively to enhance tar sand exploitation (aiming at a target of 1 million barrels per day by 1990), and progress for oil shale has been slow, but encouraging.

In his executive summary P. Desprairies says about unconventional petroleum:

> *Tar sands and heavy oils. World reserves are estimated at 300 Gt, of which only 5 to 10% are exploitable on the surface. Work for surface exploitation is most advanced in Canada, in Alberta (120 Gt in the ground), with the GCOS plant (50,000 b/d in 1967) and soon the Syncrude plant (125,000 b/d in 1978). Venezuela will probably be next with large-scale exploitation of a similar type of hydrocarbon, sometimes lighter (Orinoco Belt, 100 Gt in the ground). The cost price ex. tax for crude oil is estimated at approximately $25 (1976) per barrel, with interest at 15%, or $15 with 9% interest.*
>
> *The investment involved is high ($20-25,000 per b/d). Trials for the exploitation of sub-surface deposits are still at an early stage.*
>
> *Oil shales. The reserves in the ground are at present evaluated at 400 Gt, only 30 Gt of which are exploitable with current technology. It is likely that when production starts this will be in the United States (Colorado). The ecological problems (water, spoil matter) are considerable. Investment costs are at present estimated at between $20 and 25 (1976) per barrel, with an interest rate of 15%.*
>
> *If the hopes raised by the Garrett process (semi-in-situ combustion, production costs of $8-11/b, much less acute ecological problems) are not confirmed, shales are not likely to play a very important role until the end of the century. Substantial government aid will, in any case, be necessary for the development of the processes.*

It is worth noting that P. Desprairies gives about 60 Gt of heavy crudes, tar sands, and oil shales more or less exploitable with present technology. These 60 Gt have thus to be added to his previously quoted figure of 300 Gt*. Further progress in exploitation technology will open up wider this vast untapped potential, the role of which can become essential in the twenty-first century.

> *The unconventional oils will above all be exploited in the XXIst century, succeeding conventional petroleum in its specific applications (transport, petrochemicals). Government aid will be necessary for its production. However, one should note that once the technology has ceased to involve risk, and the companies can be content with normal industrial profitability rates (8% to 9%), the cost of these oils could be around $15 per barrel and thus not greatly exceed the current selling price of crude. They may well thus constitute in ten to fifteen years a useful stabilizing element, keeping down prices on the world oil market, provided Governments are prepared to give active support to developing the technology necessary for their production.*

Gas Resources

This study was performed by W.T. McCormick Jr., L.W. Fish, R.B. Kalisch, and T.J. Wander, of the American Gas Association [11].

Major Findings

This study quotes various recent natural gas reserve estimates from a variety of authoritative sources. The values given differ by less than 11% from the average 2500 exajoules** (EJ). For the study, estimates of proved reserves were based on the year-end 1975 world oil figure of 2382 EJ or 79 Gtce ($2170 \cdot 10^{12}$ cu.ft. or $58.6 \cdot 10^{12}$ m^3). For the natural gas resources or ultimate recoverable reserves, the estimates are less consistent and reliable than are estimates of proven reserves, as shown in Table 6 (choice of authoritative estimates).

*In fact, as mentioned above, P. Desprairies also includes deep offshore and polar oil in the unconventional oil; tertiary recovery seems to be in between.

**Values in exajoules--as given in the report--can be divided by about 30 to have values in Gtce or by about 20 to have values in Gtoe for comparison with previous sections.

Table VI. Remaining recoverable world gas resources

Source	*Year of Estimate*	*Resources Remaining Year-end 1975* (Exajoules)*
Hendricks (USGS)	*1965*	*9,470*
Ryman (Esso)	*1967*	*12,137*
Shell	*1967*	*10,221*
Coppack (Shell)	*1973*	*7,249*
Hubbert (USGS)	*1974*	*13,008*
Moody (Mobil)	*1975*	*7,641 - 8,599*
Adams and Kirby	*1975*	*5,606*
National Academy of Sciences	*1975*	*7,511*
IGT	*1977*	*9,960 - 10,395*

**(Adjustments have been made for a comparative year-end basis.)*

For the purpose of this study, the Institute of Gas Technology (IGT) estimate (332-347 Gtce*) was used since it is the most recent and is the latest in a series of consistent estimates.*

Table 7 gives the regional distribution of proven reserves and of remaining undiscovered resources. However, the identification of OPEC as a region makes the comparison with the previous tables for oil difficult.

Regarding unconventional gas resources, the study says:

Other supplemental sources of natural gas are many and varied, involving the recovery of in-place natural gas from geologic formations other than conventional type reservoirs. Knowledge of the extent of the resource base and the potential for recovering these resources on a global scale is limited. Table 8 shows estimates of the total resource base for the United States for several supplemental sources [12]. *In most cases, new technological advances are necessary to obtain economic recovery and thus the production capability is very uncertain.*

Table 7. Proven world reserves and remaining undiscovered natural gas resources by regions, 1975 (exajoules).

	Proved Reserves	Remaining Undiscovered Resources	Total*	Percent of Total World Resources
North America	310	1,640	1,950	18.6
Western Europe	152	315	467	4.4
Japan, Australia, New Zealand	41	232	273	2.6
USSR, Eastern Europe	795	2,222	3,017	18.7
China	21	380	401	3.8
OPEC	937	2,717	3,654	35.3
Latin America	42	404	446	4.3
Middle East & North Africa**	23	62	85	0.8
Africa South of Sahara**	3	12	15	0.1
East & South Asia**	37	163	200	1.9

*Excludes past cumulative production of 929 EJ (end of 1975).

**Excluding OPEC member countries.

Table 8.

Supplemental Sources of Natural Gas, US

Source	*Estimated Volume in Place (EJ)*
Coal-bed Degasification	*325-870*
Devonian Shale	*545-650*
Tight Formations	*650*
Geopressured Gas	*3,200-54,400*

If we compare these values with the values of Table 7, it is shown that these resources can each double or triple existing proven reserves, and geopressured gas alone can multiply remaining undiscovered resources by a factor of 2 to 30.

POTENTIAL PRODUCTION CURVES

All three reports analyzed here give potential production curves. These curves are definitely not forecasts, but correspond more or less to technical maxima, assuming the necessary decisions were taken in time. They offer a good subject for reflection and a good starting point for deeper studies.

A possible production curve for coal up to the year 2020 is given in Figure 5. The curve proposed by the WEC study group is a solid line, starting from $2.6 \cdot 10^9$ tce in 1975 to reach $8.7 \cdot 10^9$ tce in 2020 (passing through $3.8 \cdot 10^9$ tce in 1985 and $5.65 \cdot 10^9$ tce in 2000). This curve is growing continuously, and is mentioned as able to possibly continue to grow after 2020. However, it is also mentioned that existing economically and technically proven recoverable reserves of 640 Gt would not really permit or support such production levels; in fact, it is added that reserves could probably (in time) reach higher levels than $1200 \cdot 10^9$ tce, sufficient to support such production levels.

In the same figure, we have extrapolated this production curve further in time according to two different assumptions. The first assumption keeps the maximum production level at its 2020 peak. With reserves at $640 \cdot 10^9$ tce this production could be maintained until about 2065, and with reserves at $1200 \cdot 10^9$ tce, until 2130. The second assumption raises the production level up to $12 \cdot 10^9$ tce per year (corresponding to the 12 TWyr/yr fossil

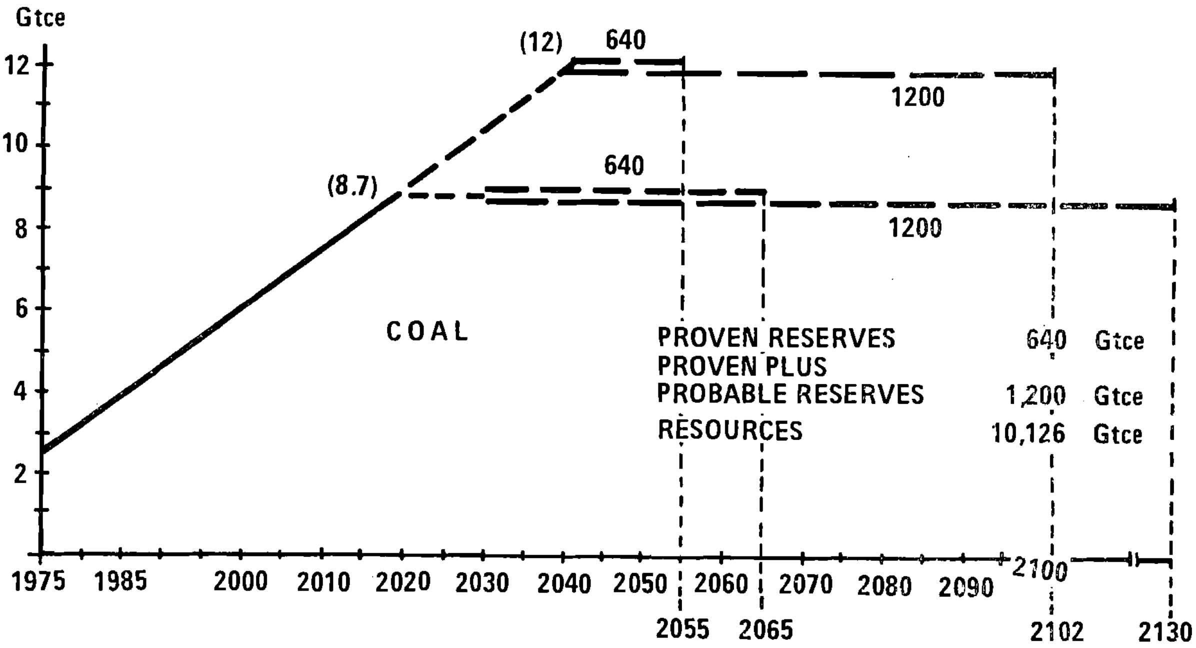

Figure 5. Coal: Possible Production and Lifetime of Reserves (after [1]).

energy demand for energy end uses in a 35 TW IIASA demand scenario for the year 2030 [13]); such a level could be reached in approximately 2040. Production could then continue only until 2055 if the reserves are only $640 \cdot 10^9$ tce, and until 2102 if the reserves are at least $1200 \cdot 10^9$ tce. Once more, let us emphasize that the increase in the reserves above the present level is more than highly probable, due to the very large amount of the resources.

For oil, a series of curves have been proposed, varying with the final amount of the remaining ultimate recoverable reserves (from a low estimate of 174 Gt to a "high" estimate of 347 Gt) and with the selected depletion rate of the reserves (equal to the 1975 value, to a medium or to an accelerated value). Depending on the assumptions, peak production occurs in about 1985 or around 1995 to 2000, and the peak levels vary between 3.3 Gt (slightly more than the present level) to about 7 Gt (which means about 10.5 TWyr/yr). Contrary to the potential production curves for coal, all the oil production curves go through a maximum, then decrease to come back to values around the present ones in the year 2020, and are finally ended by a tail extending for a few decades.

For illustration, we have chosen the curve selected by the author of the Delphi study as a basis, Figure 6 (note that the data are given in Gtce or TWyr/yr for the purpose of comparisons between the various energy resources). Assuming the

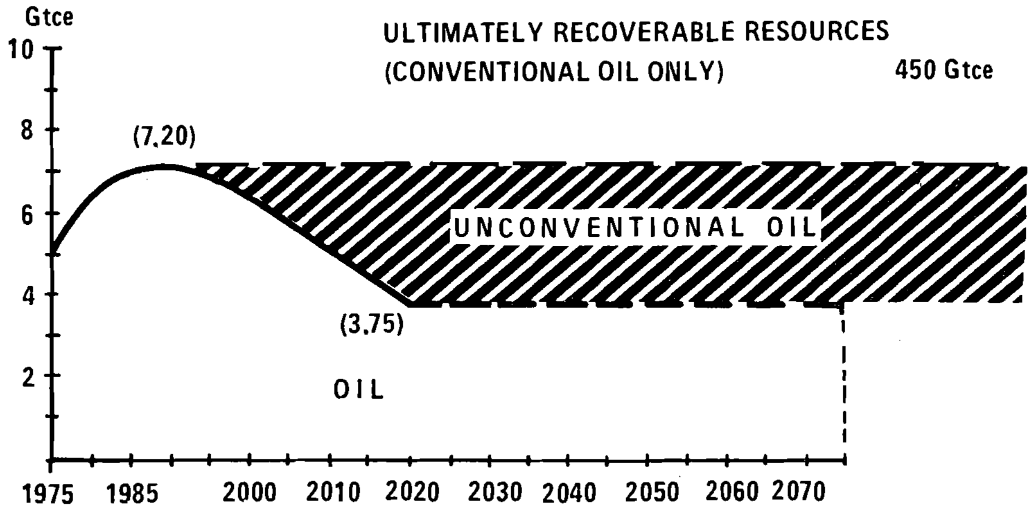

Figure 6. Oil: Possible Production and Lifetime of Resources, after [3].

remaining ultimate recoverable reserves to be 300 Gt oil (or 450 Gtce), production would peak in about 1990 at 7.2 Gtce (slightly less than 5 Gt of oil) and go down to 3.75 Gtce in 2020. Such a level of production could last until about 2075.

Two additional comments are worth making:

- The 7.2 Gtce level corresponds to about 20% of the 35 TW scenario. These 20% can represent the liquid fuel requirements for transportation.

- Most experts (those who participated in the Delphi study as well as those of the IIASA-UNITAR Conference) agree on the probable phasing-in of unconventional oil resources at the end of the century. This has been illustrated in the figure, although the substitution could, of course, follow a scheme different to the one that has been sketched. If we add known estimates of heavy crudes, tar sands, and oil shales(estimates which will probably be revised upwards now that there is an emerging economic--and political--interest in these resources), production levels of 7 Gtce could already be sustained for more than one century after 2030.

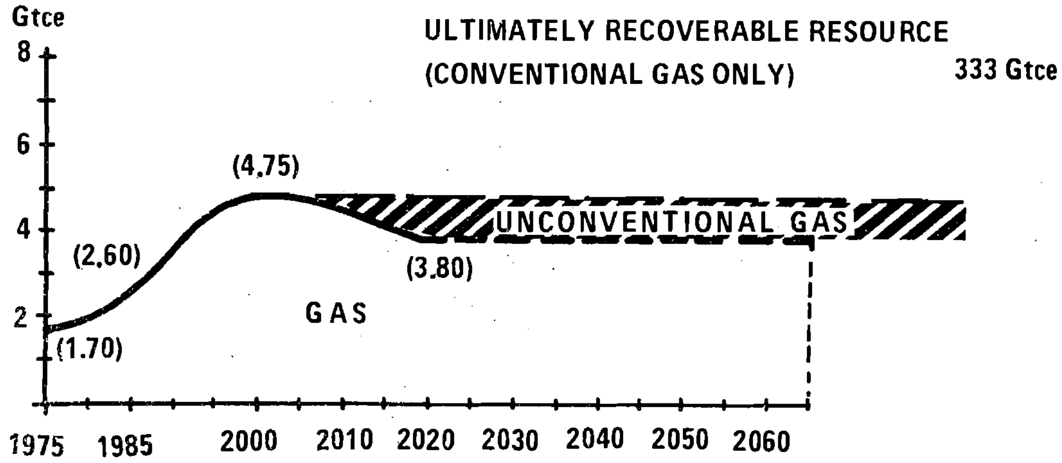

Figure 7. Gas: Possible Production and Lifetime of Resource, after [11].

Two production curves have been proposed for natural gas. They do not differ appreciably: by less than 1 percent in 2000 and less than 10 in 2020. Figure 7 shows that peak production could reach 4.75 Gtce around 2000 (which means that gas production would peak 10 to 20 years later than conventional oil production) and come down to about 3.80 Gtce in 2020. Assuming production remains at this level, it could last until 2065. During this period, unconventional natural gas could be called upon for less than 1 Gtce if it is desirable to remain on the maximum 4.75 Gtce production-consumption level.

According to many experts and to the main findings of our IIASA-UNITAR Conference, the potential for unconventional natural gas (gas in tight formations--shales or sandstones--gas in geopressure zones, gas in coal beds*, landfill gas, gas hydrates, etc.) could, in fact, allow much higher levels of production. Also, some world experts claim that world gas reserves are in reality probably higher than oil reserves. We have not taken any of these assumptions into account here--even if we share some of them--so as to remain on the conservative side.

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*The authors of the report say:

For example, using a standard factor of 200 cubic feet of natural gas per ton of coal (used by U.S. Bureau of Mines and the U.S. Energy Research and Development Administration for U.S. coal) multiplied by the total estimated world coal resources of 11.8 trillion tons results in an increase of over 2,200 EJ (73 Gtce*) to the world natural gas resource base.*

Finally, we have aggregated in Figure 8 the four possible production curves, selecting for coal the lower level of 8.7 Gtce (all results would have to be increased by 3.3 Gtce should the 12 Gtce value be preferred). This shows that, without unconventional oil and gas, fossil fuel production could peak, according to the WEC experts, at about 17 Gtce around 2000, decrease slightly to 16.25 Gtce in 2020, and continue at this level for about half a century (much longer, of course, for coal). With unconventional oil and gas, a peak of 20.65 Gtce (or possibly more) could be reached in 2020, and continue for a much longer period, assuming a timely phasing-out of conventional oil and gas and a progressive substitution by coal and unconventional oil and gas.

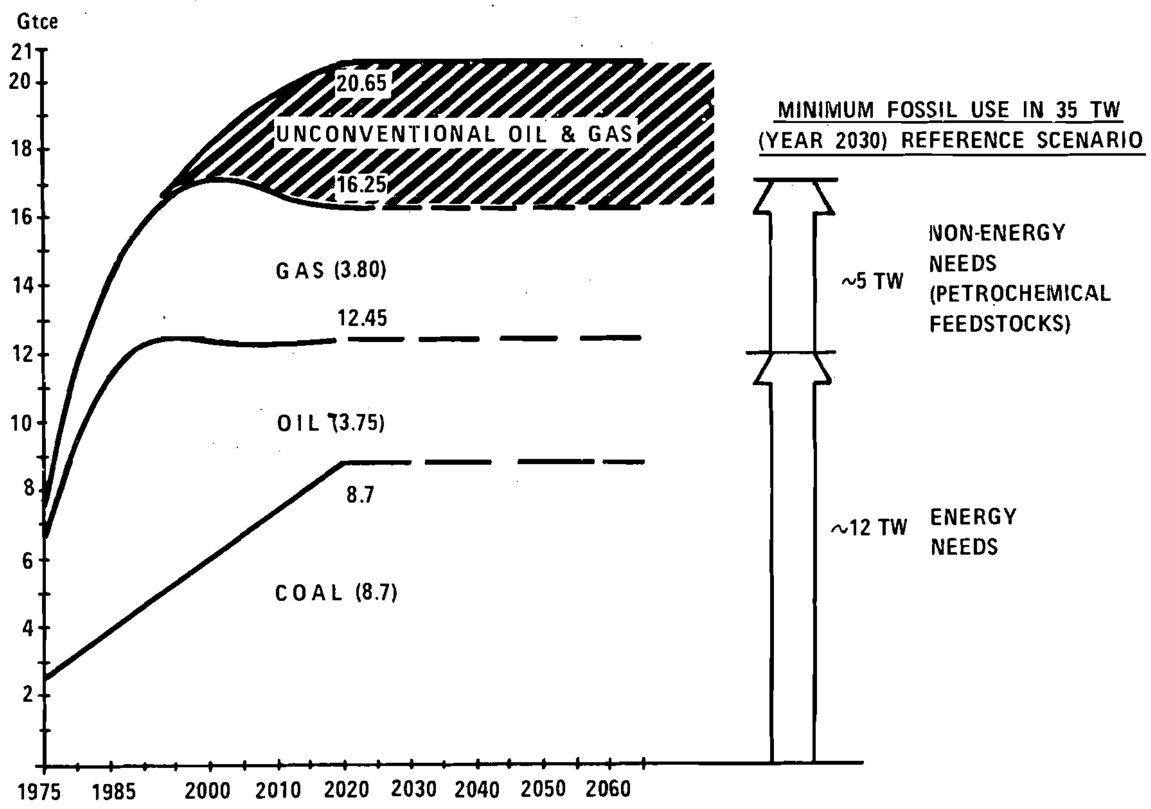

Figure 8. Total Fossil Fuels: Possible Production and Lifetimes.

CONCLUSIONS

I have not tried in this paper to emphasize our own studies but only to summarize and briefly analyze the major conclusions of the World Energy Conference on (conventional) coal, oil, and gas resources. I personally consider some of these conclusions as reasonably conservative. This means that they may be used with some confidence as a (minimum) working hypothesis on reserves and resources.

This does not mean that the WEC experts--or I--underestimate the many difficulties involved in actually producing these energy reserves. Like the experts I think that these difficulties can be overcome, and we expect that they will be. If not, no one can give the assurance that similar difficulties faced by other energy resources--such as nuclear, solar, or geothermal--will be more easily overcome. Anyhow, in such a case, mankind would settle into a long period of an exceedingly difficult energy supply.

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APPENDIX

OIL RESERVES VERSUS RESOURCES

The first important point is to understand well the different nature of energy reserves and energy resources*, and the ways to estimate them. Although we could elaborate on a three-category classification (reserves, resources, and resource-base or "occurrences", etc.), we will adhere to the McKelvey type of classification, i.e. proven, identified, economically recoverable (under present or near-term conditions) reserves, and resources including identified subeconomic, hypothetical (in known districts) and speculative (in unknown--here, undrilled--districts) resources.

Table A-1 summarizes and compares reserves and resources. It is clear that interest in reserves has always been very acute, as they serve as the basis for any planning of all oil companies. On the other hand, interest in resources has been mostly episodic, often on a "hobby" basis and generally lacking strong official support.

Table A-1. Comparison of Reserves Versus Resources.

	RESERVES	RESOURCES
INTEREST IN ...	GREAT	NONE IN THE PAST, NOW EMERGING
TIME HORIZON	10 – 30 YEARS	LONG, OR VERY LONG TERM
ECONOMIC ASPECT	MUST BE PROFITABLE	NON-PROFITABLE TODAY, "SCIENCE FICTION" TECHNOLOGY
ESTIMATED BY	INDUSTRY	MEMBER OF INDUSTRY, <u>OR</u> GOVERNMENTS (INSTITUTIONS)
DATA	MORE OR LESS RELIABLE, CONSERVATIVE, "PROPRIETARY", AND EXPLOITATION-ORIENTED	UNCERTAIN OR SPECULATIVE, BUT SCIENTIFICALLY ORIENTED
METHODS	INDUSTRIAL WORK (EXPENSIVE): EXPLORATION, DRILLING, AND MEASUREMENTS	PAPER OR COMPUTER WORK: "GEOLOGICAL", "HISTORICAL", AND GEO-INDUSTRIAL (IIASA)

* Here we concentrate especially on oil (mainly conventional) reserves and resources, excluding coal and gas resources.

The strong interest in reserves--mainly at the company level--however, does not assure a fully reliable knowledge at the aggregate level, whether national or global. At the world level, one is generally reduced to working with two independent--and competitive--estimates, namely those of the two specialized periodicals, "World Oil" and "Oil and Gas Journal" (abbreviated WO and OGJ in the following); even the UN use them, and generally do not publish independent estimates. The estimators rely independently on similar (and often, as it happens, on the same) sources of information, i.e. oil operation companies, "highly reliable" oil experts, and government officials. Some countries guard statistics as national secrets, forbidding their disclosure. Estimates by WO and OGJ differ appreciably. OGJ statistics are generally higher, supposedly due to the inclusion of natural gas liquids. By way of comparison, there follow below a few figures for oil reserves as of January 1, 1977 (all data in million barrels of oil) (Table A-2):

It is clear from these few figures that the inclusion or not of natural gas liquids cannot account for the differences. Annual estimates sometimes also vary erratically, which of course complicates any use of "historical statistics". From January 1, 1972 to January 1, 1977, the OGJ oil reserves varied from 632,553 million barrels of oil to 640,390 million barrels (revised value)--a mere 1.01 percent increase in total for the five years!--passing through a maximum on January 1, 1975 of 712,418 million barrels. During the same period, WO values* varied from 569,523 million barrels to 549,914--a 3.57%, decrease--with a maximum in 1974 to 1975 of around 570,000 million barrels.

This shows how carefully such figures must be handled, and how recent evolution can lend itself to pessimistic projections of an oil shortage in the 1980s, although the world records of drilling activities and apparent announced discoveries seem to point to the possibility of a contrary conclusion.

What about the resources? The ground is still more uncertain, as summarized in Table A-1. In Table A-3 , the two basic methods (in fact, more and more often used in combination) for assessing oil resources are briefly presented. They suggest the following comments:

*Not taking into account some annual revisions, which sometimes reach up to 8%. Revised values for January 1,1972: 556,020; revised value for January 1,1977 not yet available.

Table A-2. Comparison of Oil Reserve Data.

	World Oil (excluding natural gas liquids)	Oil and Gas Journal Original	Oil and Gas Journal Revised*
Total World	549,914	598,990	640,390
Saudi Arabia	110,187	110,000	151,400
USSR	59,900	78,100	
USA	30,942	31,300	
Iran**	48,130	63,000	
Mexico	8,000	7,000	

*Revision mainly due to correction by Saudi Arabian officials; this correction was reported in OGJ in February 1977. However, WO does not include it in its August 15 issue.

** On January 1, 1976, Iranian oil reserves were reported by WO as 66,281 million barrels; no comments were made regarding the decrease, more than 7 times the annual production.

Table A-3. Comparison of Methods for Assessing Oil Resources.

HISTORICAL STATISTICS	GEOLOGICAL ANALOGY
PRINCIPLES	
1. CHOICE OF REPRESENTATIVE STATISTICS, e.g. DISCOVERY RATE $\frac{\Delta R}{\Delta X}$	1. DEFINITION OF SEDIMENTARY REGIONS OR BASINS
2. EXTRAPOLATION TO THE FUTURE	2. COMPARISON* WITH SOME REFERENCE REGIONS OR BASINS. a. SUBJECTIVE (CURRENT METHOD) b. SCIENTIFIC (BEING DEVELOPED)
DISADVANTAGES	
– REQUIRES LONG STATISTICAL HISTORY (ONLY A VERY FEW COUNTRIES)	– POOR (AND INSUFFICIENT) KNOWLEDGE OF UNEXPLORED OR LITTLE EXPLORED BASINS
– BIASED BY POLITICAL, ECONOMIC, AND TECHNOLOGICAL FACTORS	– NO PRECISE EXPERIENCE OF ULTIMATE RECOVERY IN A REFERENCE BASIN (EVEN IN THE US)

*using historical statistics

Historical Statistics

A powerful tool is, for instance, to plot the discovery rate versus another "representative" parameter such as time, cumulative footage (Hubbert*), dollars spent on exploration, or the dollar converted to a current "barrel" of oil (Seidl**), etc.

This method has been interestingly applied by Hubbert for the US, where abundant and more or less reliable statistics exist. In view of what was written above on reserves and additions of reserves, it is very difficult to use this method valuably on a world basis. Hubbert himself, moreover, in describing his method*, warns of the difficulty of using it for "young" oil producing countries, which most countries indeed still are.

No less important must be the assurance of a non-biased statistical sampling: All other parameters must remain equal, which is rarely the case. It is worth considering the following:

- Depending on the political climate, the decisions of the companies to sometimes restrict drilling to the best known, and less risky areas (which happened for gas drilling in the US for many years), where the success ratio is generally high, but the additions to reserves small.

- Unequal access to prospective areas, areas which could increase the discovery rate appreciably (federal lands in the US, the Red Sea in Egypt, north of the 62°parallel in Norway, etc.).

- Change of regime:
  - Financial (Mexico, with oil prices frozen until 1974, preventing adequate exploration);
  - Political (i.e. Indonesia in 1976);
  - Managerial (for instance, Iran with the National Iranian Oil Company) etc.
- Technological progress.

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* Hubbert, K. in *U.S. Energy Resources: A Review as of 1972*, paper prepared for Committee on Interior and Insular Affairs, U.S. Senate, Serial No. 93-40, 92-75, Washington, D.C., 1974.

** Seidl, R.G., Implications of Changing Oil Prices on Resource Evaluations, in J. Barnea, M. Grenon, and R.F. Meyer (eds.), see [4].

Geological Analogy

The principle of this method is very interesting. It relies, however, on a good definition and knowledge of oil provinces or basins. In fact, a basin is too large an entity with too many geological features to be really valuable; the "play"--as used locally by the oil companies--would be much more appropriate, but much too small to be valuably handled on a global scale*.

Such comparisons of basins suffer from various additional difficulties:

- The international oil industry, especially outside the US, has concentrated its priority activity on the search for giant and/or supergiant deposits.
- Reference basins are generally chosen in the US, because of the better knowledge here than in many other oil provinces. Moreover the geological diversity of the US (48 conterminous states plus Alaska plus the outer continental shelf) encompasses a great number of basin types. However, the idea of a "good knowledge" of the US oil potential has been, and still is, unchallenged. It has been mentioned** that 2 percent of the total prospective sedimentary volume has been thoroughly explored.
- Contrary to what is often claimed, that we have "much more" and "much better" knowledge today than say twenty years ago, this affirmation is poorly supported by a continuing dispersion of individual assessments by the "most highly reliable experts"... In fact, we would prefer to say that our knowledge has really greatly increased, but that there is still a broad margin for improvement (for instance, recent developments on source-rocks).

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*I am exploring together with the French Petroleum Institute the possibility of an intermediate quantity, temporarily referred to as a "block". A common proposal to launch an international program on this subject is being prepared, and has already received some encouragement in private discussions with representatives of the international energy community.

**Caudle, B., and M. Dorfman, University of Texas at Austin, private communication.