PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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WORLD ENERGY RESOURCES AND DEMAND

The world energy outlook to the mid-1980s: the effect of an alternative supply path in the United States

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A brief review and interpretation of regional and world-wide trends in total energy consumption and its composition since the end of World War II is given. A review of energy-consumption projections into the 1980s – world-wide and regional – focuses on the role of international trade in oil in achieving supply–demand balances. The prospective position of the U.S. as a major oil importer is emphasized. An analysis of the sensitivity of world supply prospects to alternative assumptions concerning the growth of indigenous sources of supply in the United States of America and Western Europe is presented.

The post-war growth rate in world energy consumption averaged out to over 5% per annum. Marked shifts in regional shares and variations in regional growth rates have occurred, but regional differences in the level of per capita energy use, while narrowing, remain conspicuously wide. The sharp relative decline of coal during this period was accompanied by a dramatic relative increase in both oil and gas. The rapid growth of world energy consumption as a whole, the continued shift toward oil and the rising volume of U.S. oil imports all failed to be adequately anticipated in past energy projections.

A standard projection to the mid-1980s shows: world-wide energy growth of between $5\frac{1}{2}$ and 6%; an even faster growth rate for oil, resulting in about 115×10^6 barrels (18.3×10^6 m^3)/day in 1985 (compared to 53×10^6 b (8.4×10^6 m^3)/d in 1972); and the addition of the U.S. to the ranks of the major oil importers.

The Middle East, along with areas of lesser reserve holdings, is in all likelihood physically capable of accommodating expected oil demand to the mid-1980s. But the acute degree of dependence that this would pose for major consuming regions prompts the question of how a greatly expanded indigenous producing capability in the U.S. could blunt the one-sidedness of the demand–supply picture. Recently completed research suggests that, within an appropriate policy setting, the U.S. could probably meet all but 20% of its oil and gas internally by 1985 – and do so at real prices no higher than the $6/barrel ($38/m^3) delivered price rapidly being approached by Persian Gulf crude. Such a development, along with whatever contribution can be made by Western Europe's own petroleum-producing capability, can perhaps introduce a stabilizing element of major importance into world energy flows.

This paper begins by describing regional and world-wide trends in energy consumption since the end of World War II. This description is followed by a brief review of some past energy projections and an assessment of their accuracy in estimating future developments. In the past, there has been repeated underestimation of growth in total energy and, especially, oil demand. The conventional demand–supply picture to the mid-1980s is presented next, particularly as it bears on the emergence of the United States as a potentially large-scale importer of foreign oil, alongside such already important buyers as Western Europe and Japan. Finally, we want to re-examine world demand and supply prospects within this conventional picture of the future in the light of an alternative assumption concerning the growth of indigenous sources of supply in the United States, and in a much more cursory treatment, Western Europe. The importance of such an evaluation is underscored by the events of October and November 1973, which have once again raised questions about the risks of sustained reliance upon Middle East–North African suppliers for large volumes of petroleum.

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Past trends

World-wide energy consumption reached as estimated level of 250×10^{18} J (237×10^{15} Btu) in 1972 – equivalent to 18.4×10^6 m^3/day oil. (Some 46 % of this total, or 8.4×10^{12} m^3/day, was actually accounted for by oil.) The postwar growth rate in world energy consumption averaged out to over 5 % annually, and during the past decade reached about 5½ %. At 2 % per annum population growth, this has meant a yearly growth in per capita energy consumption of approximately 3½ % (see table 1).

Some rather striking post-World War II geographic shifts have accompanied the growth in total world energy utilization. In a number of areas, these shifts represented a continuation of trends that were in progress even earlier. For example, the Soviet Union's share of world energy consumption stood at under 2 % in 1925; just before World War II it was up to 10 %,

Table 1. World energy consumption and population, selected years, 1925–72

	total energy consumption		population	energy consumption per capita	
year	10^{18} J	10^{12} Btu	(million)	10^9 J	10^6 Btu
1925	47	44249	1890.1	24.6	23.4
1950	81	76823	2504.5	32.4	30.7
1955	105	99658	2725.6	38.6	36.6
1960	131	124046	2989.9	43.8	41.5
1965	169	160722	3281.2	51.6	49.0
1968	200	189737	3484.5	57.5	54.5
1970	226	214496	3608.6	62.6	59.4
1971	235	223522	3678.3	64.2	60.8
1972	250	237166	3747.2	66.8	63.3
		average annual percentage rates of change			
1925–50		2.2	1.1		1.1
1950–55		5.3	1.7		3.6
1955–60		4.5	1.9		2.5
1960–65		5.3	1.9		3.4
1965–70		5.9	1.9		3.9
1970–72		5.2	1.9		3.2
1950–60		4.9	1.8		3.1
1960–70		5.6	1.9		3.6
1960–72		5.5	1.9		3.5
1950–70		5.3	1.8		3.4
1950–72		5.3	1.8		3.4

Notes and Sources for tables 1–6. Data for 1968 and years preceding are taken from Sam H. Schurr (ed.), *Energy, economic growth and the environment* (Baltimore: Johns Hopkins University Press for Resources for the Future, 1972), pp. 177–87, or, in a few cases, from sources described there.

Post-1968 energy consumption was estimated on the basis of data taken from U.S. Bureau of Mines releases (for the United States); and, for other countries, from United Nations sources [*Statistical yearbook*, 1972 (New York, 1973), *World energy supplies* 1961–1970, series J, no. 15 (New York, 1972)], and British Petroleum Co., *Statistical review of the world oil industry* 1972 (1973). Population figures come from the cited two U.N. sources and (estimated for 1972 on the basis of incomplete data) from U.N. *Monthly bulletin of statistics* (July 1973).

The post-1968 energy data in the foregoing sources were consulted as to *changes* (by energy source and region) rather than adopted as to *absolute level*. The 1968 figures, to which these changes were linked, controlled as to level.

Two characteristics of the energy consumption measure used in these tables should be noted: (1) bunker fuel and non-energy uses are included; (2) the value of primary electricity (hydro, nuclear, geothermal) was calculated, not by the heat value produced, but rather by the estimated (higher) fuel inputs required at fossil-fueled thermal electric power stations.

and from its early postwar share of around 11 % it rose to approximately 15 % in 1970 (see table 2).†

Rising shares occurred elsewhere in the world in the past several decades: the other Communist countries, Latin America, Africa, and Asia all exhibit long-term increases in their relative standing. The postwar rise of Asia reflects in part the growing share of the region's developing countries; but to an even greater extent it reflects the phenomenal momentum of energy growth in Japan, whose annual postwar rates of over 10 % have been sustained to the most recent years for which figures are available.

TABLE 2. WORLD ENERGY CONSUMPTION AND POPULATION (%), BY MAJOR REGION, PERCENTAGE DISTRIBUTION, 1950, 1960, 1970, AND AVERAGE ANNUAL PERCENTAGE RATES OF CHANGE, 1960–70

	percentage distribution						average annual percentage rates of change, 1960–70		
	1950		1960		1970				
region	energy consumption	population	energy consumption	population	energy consumption	population	energy consumption	population	energy consumption per capita
North America	48.0	6.6	39.3	6.6	34.7	6.3	4.3	1.3	3.0
Canada	3.5	0.5	3.1	0.6	3.3	0.6	6.1	1.8	4.2
United States	44.5	6.1	36.1	6.0	31.4	5.7	4.2	1.3	2.9
Western Europe‡	22.8	12.1	21.0	10.9	22.3	9.9	6.3	0.9	5.3
Oceania	1.2	0.5	1.1	0.5	1.1	0.5	5.8	2.2	3.5
Latin America	3.1	6.5	4.0	7.1	4.3	7.8	6.3	2.9	3.4
Asia (excl. Communist)	5.0	32.2	6.6	32.5	9.7	34.1	9.7	2.4	7.1
Japan	2.3	3.3	3.0	3.1	5.2	2.9	11.9	1.0	10.7
Other Asia‡	2.7	28.9	3.7	29.4	4.5	31.3	7.7	2.5	5.0
Africa	1.7	8.7	1.7	9.2	1.7	9.7	5.4	2.4	3.0
U.S.S.R. and Comm. Eastern Europe	16.7	10.8	20.9	10.5	20.9	9.7	5.6	1.1	4.5
U.S.S.R.	11.0	7.2	14.4	7.2	14.9	6.7	6.0	1.2	4.7
Eastern Europe‡	5.7	3.6	6.5	3.3	6.0	2.9	4.7	0.7	4.0
Communist Asia	1.6	22.8	5.3	22.7	5.3	22.0	5.6	1.6	3.9
World	100.0	100.0	100.0	100.0	100.0	100.0	5.6	1.9	3.6

Source. See table 1.

‡ Yugoslavia is included in Western Europe throughout these tables; Turkey appears in Other Asia.

A principal offset to these long-term increases in regional shares of world-wide energy consumption has been the declining relative position of North America. Although North America retains its leading world share, with the United States occupying the top-ranking country share, its proportion of world energy consumption (which had been as high as 50 % in the mid-1920s) fell from 45 % in 1950 to under 33 % in 1970. The virtually unchanged West European share of world energy consumption – at 22 % since 1950 – reflects the fact that in 1950 the area was still in the midst of postwar recovery; in 1925 its world share had been around 35 %.

These distributional shifts in total energy consumption among different parts of the world have also been accompanied by moderately disparate trends in the growth of per capita

† For a review of pre-World War II trends, see J. Darmstadter *et al.*, *Energy in the world economy* (Baltimore: Johns Hopkins University Press for Resources for the Future, 1971), especially Part One.

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TABLE 3. WORLD ENERGY CONSUMPTION AND POPULATION, BY MAJOR REGIONS, 1950, 1960, 1970

	1950					1960					1970				
	total consumption		population	consumption per capita		total consumption		population	consumption per capita		total consumption		population	consumption per capita	
region	10^{18} J	10^{12} Btu	(million)	10^{9} J	10^{6} Btu	10^{18} J	10^{12} Btu	(million)	10^{9} J	10^{6} Btu	10^{18} J	10^{12} Btu	(million)	10^{9} J	10^{6} Btu
North America	38.8	36860	166.1	235	221.9	51.3	48701	198.7	258	245.1	78.5	74483	226.2	347	329.3
Canada	2.85	2707	13.7	208	197.6	4.1	3885	17.9	229	217.0	7.4	7039	21.4	347	328.9
United States	36.0	34153	152.3	236	224.3	47.4	44816	180.7	262	248.0	71	67444	204.8	347	329.3
Western Europe	18.4	17483	302.4	61	57.8	27.4	26066	326.5	84	79.8	50.5	47874	356.4	143	134.3
Oceania	0.94	890	12.2	77	73.0	1.48	1398	15.4	96	90.8	2.6	2451	19.2	135	127.7
Latin America	2.52	2397	161.9	15.6	14.8	5.2	4939	212.4	25	23.3	9.6	9130	282.0	34	32.4
Asia (excl. Comm.)	4.01	3804	805.4	5	4.7	8.7	8228	970.6	9	8.5	22	20819	1231.3	18	16.9
Japan	1.83	1739	82.9	22	21.0	3.9	3672	93.2	41.5	39.4	12	11255	103.4	116	108.9
Other Asia	2.17	2063	722.5	3	2.9	4.8	4556	877.4	5.5	5.2	10	9564	1127.9	9	8.5
Africa	1.37	1297	217.0	6.3	6.0	2.3	2162	276.0	8.2	7.8	3.9	3677	349.5	11	10.5
U.S.S.R. and Comm. Eastern Europe	13.5	12842	269.8	50.2	47.6	27.4	25973	312.9	87.5	83.0	47.2	44758	348.4	136	128.5
U.S.S.R.	8.9	8427	180.0	49.4	46.8	18.9	17898	214.4	88	83.5	33.8	31994	242.8	139	131.8
Eastern Europe	4.65	4414	89.7	52	49.2	8.5	8075	98.5	86.5	82.0	13.5	12764	105.6	128	120.9
Communist Asia	1.32	1250	569.8	2.3	2.2	6.9	6579	677.5	10.2	9.7	12	11304	795.6	15	14.2
World	81	76823	2504.5	32.4	30.7	131	124046	2989.9	43.8	41.5	226	214496	3608.6	63	59.4

Source. See table 1.

energy consumption, both during the long-range time-span since the 1920s and during the briefer recent period highlighted in table 2. During the 1960–70 decade, for example, per capita energy growth ranged from around 3 % in the U.S. to over 10 % in Japan, with a number of regions clustered in the 4–5 % per capita growth rate bracket.

But regional differences in the level of per capita energy use, while narrowing, remain dramatically wide, as can be seen in table 3. In 1970 U.S. per capita energy consumption of 347×10^9 J and that of Canada, which was only slightly lower, were more than two and one-half times the level of the next ranking regions – Western Europe, the U.S.S.R., and Oceania, all of which recorded per capita figures in the vicinity of 137×10^9 J. And the more extreme disparity is reflected in the fact that North American per capita consumption was between 30 and 40 times the levels prevailing in Africa and the developing portions of Asia.

If North America's level of per capita energy consumption in 1925 (roughly 185×10^9 J) had remained unchanged throughout the period 1925–70, it would still have been some 30 % above the next highest area (Western Europe) tabulated for the year 1970 and nearly 20 times as high as the developing countries of Asia and Africa. To be sure, trends and levels in per capita energy consumption are not synonymous with per capita income or gross national product; nor are the latter measures, in turn, truly reflective of living standards, however defined. None the less, there is unquestionably a sufficiently close connexion between levels of per capita energy consumption and general economic development to permit one to point to the more extreme disparaties of table 3 as yet another sign that substantial improvement in living standards in the years ahead will constitute a growing burden on world energy supplies.

TABLE 4. WORLD ENERGY CONSUMPTION: PERCENTAGE DISTRIBUTION BY SOURCE 1950–72

	1950	1960	1965	1968	1970	1971	1972
coal†	55.7	44.2	39.0	33.8	31.2	29.9	28.7
oil‡	28.9	35.8	39.4	42.9	44.5	45.2	46.0
natural gas	8.9	13.5	15.5	16.8	17.8	18.3	18.4
primary electricity§	6.5	6.4	6.2	6.5	6.5	6.6	6.9
total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10^{15} J	80	130	168	200	226	236	250
10^{18} Btu	76.8	124.0	160.7	189.7	214.5	223.5	237.2

Source. See table 1.

† Principally bituminous coal, but also including anthracite, lignite, and a variety of low-quality coals.

‡ Including, where known, natural-gas liquids.

§ For 1971, the 'primary electricity' components were as follows [Joules converted at the fuel-input equivalent (see footnote to table 1)]:

	10^9 kW h	10^{15} J	as % of world energy consumption
geothermal	5.6	64	0.03
nuclear	103.9	1195	0.5
hydro	1243.3	14300	6.1

Tables 4, 5 and 6 provide a picture of postwar shifts in the role of the different energy sources. The sharp relative decline of coal during this period was accompanied by marked relative increases in both oil and gas. The latter two accounted for 38 % of world-wide energy consumption in 1950 and 64 % in 1970; concurrently, coal experienced a relative decline, from 56 to 29 %. The primary electricity share – hydro along with a thus far modest but rising nuclear component – remained essentially unchanged.

To a greater or lesser extent, similar changes – at least the shift from coal to oil and gas – occurred in principal regions of the world. In no area did the share of coal fail to decline. In each area, the share of natural gas was higher in 1970 than in 1950. This was true also of oil consumption in each area, with the exception of Latin America; in that region (where oil had already constituted 73 % of energy consumption in 1950) the oil proportion dropped somewhat, while that for gas rose sharply. Only in two regions – Eastern Europe and China – did coal continue to contribute more than half of total energy consumption in 1970. In Western Europe, not only was there a sharp decline in coal's relative share in less than two decades from over

TABLE 5. WORLD ENERGY CONSUMPTION: AVERAGE ANNUAL PERCENTAGE RATES OF CHANGE, BY SOURCE, SELECTED PERIODS, 1950–72

	1950–60	1960–65	1965–70	1970–72	1960–70	1950–70	1960–72	1950–72
coal	2.5	2.8	1.4	0.9	2.0	2.3	1.8	2.1
oil	7.1	7.4	8.6	6.9	8.0	7.6	7.8	7.5
natural gas	9.4	8.3	8.9	6.8	8.6	9.0	8.3	8.8
primary electricity	4.8	3.9	7.6	8.3	5.7	5.2	6.2	5.5
total	4.9	5.3	5.9	5.2	5.6	5.3	5.6	5.3

Source. See table 1 and footnotes to table 4.

three-fourths to little over one-fourth, but its absolute use also fell. Concurrently, oil and gas went from 15 to 62 %. Japan's energy pattern disclosed similarly dramatic shifts. The Soviet picture is highlighted by a big postwar rise in the share of natural gas – from 2 to 22 %. The changing U.S. pattern was far less remarkable, for the early pre-eminence of the United States in world oil and gas resulted in important shares for these fuels in the country's total energy consumption far earlier than in most other regions. Thus, the proportion of oil in U.S. energy consumption rose rather modestly between 1950 and 1970, the sharply declining relative position of coal (with, incidentally, only slight long-term absolute growth) being principally compensated for by natural gas. In the past several years, however, U.S. oil consumption has advanced at a disproportionately fast rate as gas output levelled off, power-station coal utilization encountered tight environmental constraints, and oil demand in the transport sector accelerated.

This dependence on oil, as a 'balancing' element in U.S. energy requirements, has given rise to substantially expanded U.S. oil imports during the past ten years, as table 7 shows. Rising from 334×10^3 m^3/day in 1962 to 747×10^3 m^3/day in 1972 – or at a growth rate of $8\frac{1}{2}$ % per year – the oil import share of U.S. oil consumption has gone from 20 to 30 % (and earlier this year was running at close to 35 %). In terms of national energy consumption in the aggregate, however, U.S. oil imports stand far below comparable shares elsewhere. In Western Europe, oil imports went from 37 % of total energy consumption in 1962 to nearly 60 % in 1972; in Japan, from 44 to 73 %; while, for the United States, the increase was from 9 to $13\frac{1}{2}$ %.

REVIEW OF PROJECTIONS

Three principal lines of development discussed earlier – the rapid growth of world energy consumption as a whole, the continued shift towards oil, and the rising volume of U.S. oil imports – all failed to be adequately anticipated in the succession of energy projections which have appeared since around 1960. The forecasting record, summarized in table 8, is designed for impressionistic purposes only. A retrospective analysis comparing the different projection

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TABLE 6. PERCENTAGE DISTRIBUTION OF ENERGY SOURCES FOR MAJOR REGIONS, 1950 AND 1970

	1950							1970						
				primary	total						primary	total		
10^{18} J	coal	oil	natural gas	elec-tricity	%	10^{18} J	10^{15} Btu	coal	oil	natural gas	elec-tricity	%	10^{18} J	10^{15} Btu
North America	38.0	38.7	16.7	6.4	100.0	38.8	36.86	18.3	43.7	32.1	6.0	100.0	78.5	74.48
Canada	40.6	28.6	2.8	27.9	100.0	2.85	2.71	9.6	41.3	26.9	22.2	100.0	7.4	7.04
United States	37.8	39.5	18.0	4.7	100.0	36.0	34.15	19.1	43.9	32.7	4.3	100.0	71	67.44
Western Europe	77.4	14.3	0.3	8.0	100.0	18.4	17.48	27.4	55.6	6.1	10.8	100.0	50.5	47.87
Oceania	65.3	27.3	—	7.4	100.0	0.94	0.89	39.8	48.6	2.2	9.3	100.0	2.6	2.45
Latin America	9.8	72.9	8.3	9.0	100.0	2.52	2.40	4.9	67.8	18.4	8.8	100.0	9.6	9.13
Asia (excl. Comm.)	53.3	28.5	1.4	16.9	100.0	4.01	3.80	23.3	64.1	6.2	6.4	100.0	22	20.82
Japan	61.9	5.0	0.2	32.9	100.0	1.83	1.74	22.4	68.8	1.3	7.5	100.0	12	11.26
Other Asia	46.0	48.3	2.4	3.3	100.0	2.17	2.06	24.3	58.7	11.8	5.2	100.0	10	9.56
Africa	61.4	36.9	—	1.7	100.0	1.37	1.30	43.5	48.7	1.5	6.2	100.0	3.9	3.68
U.S.S.R. and Comm. Eastern Europe	81.4	14.6	2.3	1.7	100.0	13.5	12.84	49.6	28.7	18.5	3.1	100.0	47.2	44.76
U.S.S.R.	75.6	19.7	2.5	2.3	100.0	8.9	8.43	40.4	33.3	22.5	3.8	100.0	33.8	31.99
Eastern Europe	92.5	4.8	2.0	0.7	100.0	4.65	4.41	72.7	17.4	8.4	1.5	100.0	13.5	12.76
Communist Asia	92.8	0.9	—	6.3	100.0	1.32	1.25	89.4	8.2	NA†	2.4	100.0	12	11.30
World	55.7	28.9	8.9	6.5	100.0	81	76.82	31.2	44.5	17.8	6.5	100.0	226	214.50
10^{18} J	45.1	23.4	7.19	5.28				70.6	100.7	40.3	14.7			
10^{15} Btu	42.80	22.20	6.82	5.00				66.90	95.48	38.21	13.91			

Sources. See table 1 and footnotes to table 4.

† The UN (basic source for these data; see notes to table 1) shows no figures on China's natural-gas production and consumption. A recent analysis puts China's natural-gas production at 12.1×10^9 m^3 (417×10^{15} J; 0.4×10^{15} Btu) in 1965 and 34.0×10^9 m^3 (1.25×10^{18} J; 1.2×10^{15} Btu) in 1971 (C. S. Chen and K. N. Au, The Petroleum industry of China, *Die Erde*, Heft 3–4, 1972 (Berlin), p. 319). Such a quantity would clearly raise the estimate of China's energy consumption – shown above and in tables 2 and 3 – quite markedly. Another estimate (*Oil and Gas J.* 20 August 1973) credits China with only about 20% of this amount of gas output.

TABLE 7. ENERGY CONSUMPTION, OIL CONSUMPTION, AND OIL IMPORTS: UNITED STATES, WESTERN EUROPE AND JAPAN, 1962 AND 1972

	1962			1972		
	United States	Western Europe	Japan	United States	Western Europe	Japan
	10^6 m³/day (10^6 barrels/day)					
energy consumption (oil equivalent)	3.7 (23.27)	2.22 (13.96)	0.358 (2.25)	5.57 (35.05)	3.79 (23.84)	1.05 (6.58)
oil consumption	1.63 (10.23)	0.832 (5.24)	0.153 (0.96)	2.54 (15.98)	2.25 (14.20)	0.762 (4.80)
oil imports†	0.335 (2.12)	0.825 (5.19)	0.156 (0.98)	0.75 (4.74)	2.23 (14.06)	0.76 (4.78)
from Middle East–North Africa‡	0.054 (0.34)	0.604 (3.80)	0.115 (0.72)	0.11 (0.70)	1.80 (11.30)	0.60 (3.78)
from elsewhere	0.283 (1.78)	0.22 (1.39)	0.041 (0.26)	0.64 (4.04)	0.44 (2.76)	0.16 (1.00)
	percentage of energy consumption					
oil consumption	44.0	37.5	42.7	45.6	59.6	73.0
oil imports†	9.1	37.2	43.6	13.5	59.0	72.6
from Middle East–North Africa‡	1.5	27.2	32.0	2.0	47.4	57.4
from elsewhere	7.6	10.0	11.6	11.5	11.6	15.2
	percentage of oil consumption					
oil imports†	20.7	99.0	102.1	29.7	99.0	99.6
from Middle East–North Africa‡	3.3	72.5	75.0	4.4	79.5	78.6
from elsewhere	17.4	26.5	27.1	25.3	19.4	20.9
	percentage of oil imports					
from Middle East–North Africa‡	16.0	73.2	73.5	14.9	80.4	78.9
from elsewhere	84.0	26.8	26.5	85.1	19.6	21.1

Sources. Data for 1962 based on Joel Darmstadter *et al.*, *Energy in the world economy* (Baltimore: Johns Hopkins University Press for Resources for the Future, 1971), and British Petroleum Co., *Statistical review of the world oil industry*, 1962; data for 1972 based on British Petroleum Co., *Statistical review of the world oil industry*, 1972.

† Imports are gross of exports. Thus, they exclude product exports from West European refineries. And for Japan, excess of imports over consumption arises because of small quantities of product exports, refinery losses and (presumably) independent construction of the two series. By showing gross rather than net imports, we overstate slightly the degree of foreign dependence. The overstatement matters, if at all, only in the case of West Europe.

‡ Includes negligible quantities from West Africa in 1962.

studies as well as a comparison between the projections and actual performance cannot be adequately detailed here.§

This said, the degree of underestimation disclosed by the table is still worth pondering. As we might expect, there is less error in total energy projections than in those on oil. But even for the total the projections have been markedly conservative. In the U.S. case, which we have dissected in some detail elsewhere,‖ the progressively declining relationship – observed for decades

§ Comparability is impaired for a number of reasons: definitions do not always agree; a varying amount of historical information may have been available for the various studies, even though ultimately published in the same year; projected time-intervals do not precisely correspond to the actual time lapse used in the comparison. Moreover, assumptions governing the different forward estimates – both as to total energy and particular fuels – would need to be standardized or, at least, made explicit in order to permit a diagnosis of what went wrong and for what reason.

‖ Sam H. Schurr (ed.), *Energy, economic growth, and the environment* (Baltimore: Johns Hopkins University Press for Resources for the Future, 1972), pp. 168–171.

– between energy growth and g.n.p. growth did not endure into the later part of the 1960s as had been assumed. What was not foreseen, among other things, was the halt to efficiency improvements in the U.S. electric power sector and the acceleration in demand growth for motor vehicle fuels. Since 1970 the U.S. energy/g.n.p. ratio seems once again to have reverted to its long-term downward trend. It does seem, however, from the rather erratic energy/g.n.p.

TABLE 8. REVIEW OF SELECTED PAST ENERGY CONSUMPTION PROJECTIONS

	actual data†		projections			
region	period	average annual growth rate (%)	source	year published	period	average annual growth rate (%)
			total energy consumption			
World	1960–70	5.6	(A)	1966	1960–70	4.6
					1970–80	4.8
			(B)	1966	1960–80	5.0
Western Europe	1960–70	6.3	(C)	1960	1955–75	2.8
			(A)	1966	1960–70	4.4
					1970–80	4.0
			(B)	1966	1964–70	4.2
					1970–80	4.1
United States	1960–70	4.2	(D)	1963	1960–70	2.9
					1970–80	2.8
			(A)	1966	1960–70	3.6
					1970–80	3.3
Japan	1960–70	11.9	(A)	1966	1960–70	9.1
					1970–80	7.0
			(B)	1966	1964–70	10.0
					1970–80	6.9
			oil consumption			
Western Europe	1962–72	10.5	(B)	1966	1964–80	4.1‡
United States	1962–72	4.6	(A)	1966	1960–70	3.5
					1970–80	2.7
			(E)	1971	1965–75	3.4
					1975–80	2.9
			(F)	1968	1965–80	3.1
Japan	1962–72	17.5	(B)	1966	1964–70	14.3
					1970–80	8.3
			oil imports			
United States	1962–72	8.4	(F)	1968	1965–80	3.2
			(E)	1971	1965–75	3.5
					1975–80	2.6
			(A)	1966	1960–70	4.4
					1970–80	4.2§

Sources. (A) European Coal and Steel Community, *Review of the long-term energy outlook of the European Community.* (B) O.E.C.D., *Energy policy,* (C) O.E.E.C., *Towards a new energy pattern in Europe.* (D) Hans Landsberg, Leonard L. Fischman and Joseph L. Fisher, *Resources in America's future* (Baltimore: Johns Hopkins Press for Resources for the Future). (E) Sam H. Schurr, Paul T. Homan and associates, *Middle Eastern oil and the western world: prospects and problems* (New York: American Elsevier Publishing Co.). (F) U.S. Department of the Interior, *United States petroleum through 1980.*

Note. Differences in definitional practices among the various projection studies impairs exact comparison, even of growth rates.

† Taken from tables 1 or 7 above.

‡ Highest of range shown in source (B).

§ Midpoint of range shown in source (A).

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elasticities tabulated for a number of countries (see table 9), that this familiar (and perhaps over-used) relationship may have limited utility as a basis for forecasting energy consumption.

More spectacular misjudgements, evident in table 8, concern the role of oil in Western Europe's energy balance and of oil consumption and imports into the United States. In the case of recent trends in Western Europe's oil consumption, a key element seems to lie in the fact that the 1966 O.E.C.D. study, *Energy policy*, allowed for a far greater role for coal between 1964 and 1970 (though not an expanding one) than actually took place. In this respect the 1966 O.E.C.D. study was only the latest in a succession of projections which failed to anticipate the rapidly shrinking role of the West European coal industry.

TABLE 9. ENERGY CONSUMPTION GROWTH RELATIVE TO G.N.P. GROWTH, SELECTED COUNTRIES, 1960–71

	1960–65 average annual % rate of change in:			1965–71 average annual % rate of change in:		
	(1) energy consumption	(2) real g.n.p.	(3) elasticity (1)/(2)	(1) energy consumption	(2) real g.n.p.	(3) elasticity (1)/(2)
United States	3.9	4.8	0.81	4.5	3.1	1.45
Canada	6.2	5.6	1.11	6.1	4.8	1.27
United Kingdom	2.5	3.3	0.76	1.6	2.5	0.64
France	5.5	5.8	0.95	5.7	5.7	1.00
West Germany	5.8	5.0	1.16	4.2	4.6	0.91
Italy	9.1	5.3	1.72	7.8	5.2	1.50
Sweden	5.8	4.9	1.18	6.1	3.3	1.85
Switzerland	6.8	5.3	1.28	6.0	3.9	1.54
Spain	5.8	8.6	0.67	8.9	6.0	1.48
Belgium–Luxembourg	6.1	4.8	1.27	4.9	4.6	1.06
Netherlands	7.8	5.0	1.56	7.9	5.3	1.49
Denmark	8.6	5.2	1.65	5.2	4.4	1.18
Japan	10.0	10.0	1.00	11.8	11.2	1.05
Australia	6.3	5.0	1.26	4.6	5.1	0.90
India	7.0	3.3	2.12	3.5	4.2	0.83
Venezuela	5.7	7.7	0.74	2.6	4.2	0.56
Mexico	4.6	7.0	0.66	7.9	6.3	1.25

Sources. Data for 1960–5 from Darmstadter, *Energy in the world economy*, *op. cit.*; energy data 1965–71 from United Nations, *World Energy Supplies*, series J, various numbers; GNP data, 1965, from U.S. Agency for International Development, 'Gross National Product – growth rates and trend Data by Region and Country', Release RC-W-138, 1 May 1973.

Note. The energy consumption growth rates shown here may differ slightly from figures in other tables because of differences in derivation.

As for U.S. oil demand and imports, we have already referred to some of the critical factors at work in that development: severe environmental restrictions against the use of coal, lagging natural gas output, and accelerated demand growth in the transport sector, all put pressure on oil demand, which, given the levelling off in America's own oil production, have contributed to a totally unforeseen need for foreign oil in the quantities which have been entering the country.

The conventional international picture for the mid-1980s

Two standard representations of future energy developments, which have recently become available, are those of the National Petroleum Council (in the United States) and the Organization for Economic Cooperation and Development.† We have depended upon these studies (modified, to some extent) as well as upon several subsidiary analyses in fashioning the summary projections of tables 10 and 11.‡

Table 10. Illustrative projections of world energy consumption, by source, 1972–85

	1972			1972–85 average annual % rate of change	1985		
	10^{15} J/day	oil equivalent (10^6 b/d)	%		10^{15} J/day	oil equivalent (10^6 b/d)	%
total	709	116	100.0	5.7	1460	239	100.0
coal	202	33	28.7	2.4	275	45	18.8
oil	324	53	46.0	6.2	709	116	48.5
gas	128	21	18.4	6.4	287	47	19.7
primary electricity	49	8	6.9	11.0	190	31	13.0
(hydro)	(43)	(7)	(6.1)	(6.0)	(92)	(15)	(6.3)
(nuclear)	(6)	(1)	(0.8)	(24.0)	(98)	(16)	(6.7)

Sources. Data for 1972 from tables 1 and 4 (and sources thereto) converted from Btu's into barrels/day oil equivalents. 1985 by assumption, but representing in large part an adaptation, with some modifications, of projections to 1980 in O.E.C.D., *Oil, the present situation and future prospects* (Paris, 1973). Data shown conform to concepts described in notes to table 1. See text for additional comments.

Four central features of the standard representation of projected trends in world energy consumption to the mid-1980s are: first, a continued rapid world-wide growth of between $5\frac{1}{2}$ and 6 % per annum in total energy demand; secondly, a correspondingly rapid – indeed somewhat faster – expansion in oil demand, resulting in world-wide consumption of about 18.4×10^6 m^3/day in 1985 compared to around 8.4×10^6 m^3/day in 1972 (a continuously declining coal share is offset by comparatively fast growth for nuclear energy and natural gas); thirdly, perhaps the most fundamental change over the past patterns of world energy flows which is presently foreseen is the sharply rising volume of U.S. oil imports – up from 800×10^3 m^3/day in 1972 to about 2.1×10^6 m^3/day in 1985; and, fourthly, in spite of what, in historical terms, is a significant expansion of Western Europe's indigenous oil-producing capability, the preeminent share of that region's oil needs (and, of course, that of Japan also) will have to be met by imports.

It is assumed in this projection that the growth in energy requirements in relationship to that in economic growth will generally remain at or above unity for the major consuming regions, and substantially above unity elsewhere in the world. This implies that the real price of oil, while it can reasonably – some would say inescapably – be expected to rise during the next

† National Petroleum Council, *U.S. Energy outlook* (Washington, December 1972); and Organization for Economic Cooperation and Development, *Oil – the present situation and future prospects* (Paris, 1973).

‡ A literal adoption, jointly of the N.P.C. and O.E.C.D. projections, is impossible since there are some differences in definitions, assumptions, and time-periods surveyed; there is also the fact that the N.P.C. postulates a number of alternative cases while the O.E.C.D. works with a single set of projected figures.

TABLE 11. ILLUSTRATIVE PROJECTIONS OF WORLD OIL CONSUMPTION AND POSSIBLE PRODUCTION LEVELS, SELECTED AREAS, 1972–1985

	1972†		1985	
	$10\ m^3/d$	10^6 b/d	$10\ m^3/d$	10^6 b/d
consumption				
United States	2.54	15.98	4.10	25.8
Canada	0.26	1.66	0.48	3.0
Western Europe	2.26	14.20	4.50	28.3
Japan‡	0.76	4.80	2.32	14.6
U.S.S.R., China, Eastern Europe	1.27	7.99	3.29	20.7
Other	1.28	8.07	3.75	23.6
total	8.37	52.70	18.4	116.0
actual (1972) and possible production levels				
United States	1.78	11.18	1.96	12.3
Canada	0.29	1.84	0.71	4.5
Western Europe	0.07	0.44	0.64	4.0
Latin America	0.79	4.98	1.18	7.4
Middle East	2.86	17.98	7.79	49.0
North Africa	0.59	3.74	1.07	6.7
West Africa	0.33	2.08	0.98	6.2
U.S.S.R., China, Eastern Europe	1.41	8.87	3.29	20.7
Indonesia, Australia, other Eastern Hemisphere	0.29	1.83	0.83	5.2
total	8.41	52.92	18.4	116.0
net import requirements				
United States	0.76	4.80	2.14	13.5
Western Europe	2.18	13.76	3.86	24.3
Japan‡	0.76	4.80	2.32	14.6
total	3.70	23.36	8.32	52.4
balancing production and net exports				
production:				
Middle East	2.86	17.98	7.79	49.0
North Africa	0.59	3.74	1.07	6.7
West Africa	0.33	2.08	0.98	6.2
Latin America	0.79	4.98	1.18	7.4
Indonesia, Australia, other Eastern Hemisphere	0.29	1.83	0.83	5.2
total	4.86	30.61	11.85	74.5
less: own consumption, above areas	1.28	8.07	3.75	23.6
equals: net exports, above areas	3.58	22.54	8.10	50.9
plus: net exports, Canada	0.0286	0.18	0.24	1.5
net exports, U.S.S.R., China, Eastern Europe	0.14	0.88	—	—
equals: net exports	3.75	23.60	8.34	52.4

Source. Data for 1972 from British Petroleum Co., *Statistical review of world oil industry*, 1972. Projections for 1985: *total* consumption (and production) taken from table 10. Distribution by consuming and producing countries, using a variety of sources (in some cases modified). These included National Petroleum Council. *U.S. energy outlook* (Washington: December 1972); 'Energy: the changed and changing scene', paper by Geoffrey Chandler, the Institute of Petroleum meeting, 7 June 1973; and O.E.C.D., *Oil, the present situation and future prospects* (Paris, 1973). The U.S. figure is the N.P.C.'s Case III – involving assumption of moderately high degree of import dependence. See text for additional remarks.

† For definitional and estimating reasons, there are minor statistical discrepancies between production and consumption (and between net imports and net exports) for 1972.

‡ Japanese oil production (insignificant in 1972) is not shown separately for 1972 or considered for 1985.

decade, will none the less fail to restrain a vast expansion in oil consumption, essentially in line with past trends. World-wide (as opposed to localized) oil supply constraints are ruled out. Clearly, such assumptions – especially the last two – are highly debatable.

The net import requirements for oil of the United States, Western Europe and Japan combined are seen, in these assumptions to rise from 3.7×10^6 m^3/day in 1972 to around 8.3×10^6 m^3/day in 1985, implying an average annual rise of 6.5 % and a cumulative thirteen year total of about 29×10^9 m^3. This total may be compared to currently published proved reserves figures for the potential net exporting regions of the world (excluding, that is, the United States, Western Europe, and the Communist countries) as follows:

	10^9 m^3	10^9 barrels
Middle East: Saudi Arabia	29	183
other	27.4	172
North Africa	13.2	83
all other	12.9	81
total	82.5	519

The indispensability of future Middle East supplies, and, apparently, of Saudi Arabia within the Middle East, in accommodating this particular world demand–supply hypothesis stands out unmistakably. Substantial new reserves will of course have to be added to maintain a stable production-to-proved reserves ratio in the mid-1980s. Purposeful withholding of supplies apart, the reserves here credited to the net exporting regions are, moreover, not going to be at the exclusive disposition of the three principal importing regions. Some 12.7×10^9 m^3 during 1972–85 may be consumed within the net exporting area itself.

A conventional view of the U.S. position in 1985

Since it is the changed U.S. position which figures so prominently in conjecture about evolving relationships in the world oil trade, some words about the United States in particular seem called for. As already noted, most recent attempts to scan the future energy demand–supply situation in the United States have concluded that the relative U.S. dependence on imported oil seems likely to continue rising for years to come. The recently completed comprehensive report by the N.P.C. cited earlier analysed a variety of U.S. demand–supply 'scenarios' up to 1985. Total energy consumption is projected to increase at an annual growth rate of somewhat over 4 %. The N.P.C. examined a variety of alternative supply possibilities, ranging from case I, with its high domestic output potential (2.46×10^6 m^3 of oil per day), to case IV – labelled 'continuation of current trends' – with its low output potential (1.65×10^6 m^3 of oil per day). Most often quoted are two intermediate supply evaluations ('cases II and II'), yielding figures on oil import dependency in 1985 ranging from 38 to 53 %, or 1.43×10^6 to 2.22×10^6 m^3/day. As does the N.P.C. when dealing with a single, middle of-the-range set of estimates, we have adopted case III for the illustrative purposes of table 11.

It is important to underscore the fact that the N.P.C. projections flow directly from certain implicit or explicit assumptions: growth in energy demand and compositional shifts in energy sources and forms not unlike those of recent years; minimal contribution from synthetics; and real price increases which are assumed neither to dampen demand growth nor to stimulate

domestic output to levels sufficient to keep imports below the 38–53 % range indicated in the N.P.C.'s intermediate supply cases.

The prospects confronting the U.S. and the other prospective principal oil importing regions to the mid-1980s gives rise to a key question of enormous interest and concern: Does the United States (and, to a lesser extent, Western Europe) have the flexibility substantially to alter the future supply–demand outlook through purposeful measures to expand domestic output? And what would be the implications if such expandability turned out to be feasible?

Analysis of available U.S. options

As part of the broader Energy Policy Project of the Ford Foundation, Resources for the Future (R.f.F.), has recently undertaken an intensive analysis of alternative energy supply possibilities for the United States. Our tentative findings confirm the view that present shortages of domestically produced energy are not the result of any shortage of undeveloped resources in the ground. The nation simply has not followed policies conducive to the development of domestic supply in the last 15–20 years. Certain policies – for example, import controls and special tax provisions – were supposed to stimuate domestic supply and no doubt they did have some effect. However, it takes a consistent package of policies to bring about increased supply and in the last 15 years the incentive of a favourable rate of return has been missing from the package. Oil and natural gas prices have been directly and indirectly kept too low. As a result, the domestic oil producing industry has actually been liquidating its assets. The drilling of oil and gas wells has lagged. In 1956, the postwar peak year, the industry drilled over 57 000 wells. Last year only 29 000 wells were drilled – the U.S. is now almost back to the 1946 level of well-drilling. This can hardly be said to be a vigorous programme of developing domestic capacity.

There are indications that the situation is improving. Crude-oil prices which in constant dollars have declined almost continuously since 1957 are turning around. Natural gas prices are beginning to increase, although natural gas, a premium fuel, in 1972 was priced, on the average, at 19 cents per 10^9 J at the wellhead, while oil was selling at 57 cents. However, natural gas prices in particular and oil prices to some extent are still subject to the hazards of regulatory, judicial, and political processes.

Various estimates exist of the amount of oil and gas remaining to be found, developed, and produced in the U.S. Industry estimates such as those made by the National Petroleum Council and in the reports of the Potential Gas Committee may well underestimate the magnitude of the resources available to the nation. Be that as it may, there does not seem to be any serious question about the adequacy of natural resources of oil and gas in the U.S. to support any reasonable degree of self-sufficiency in energy during the next few decades. Finding, developing and producing those resources will, of course, be a monumental task. As yet there is no assurance that the nation will decide to undertake the task.

Coal resources are undeniably large, although increased utilization of coal is presently hampered by serious environmental problems in both production and utilization. A policy designed to achieve substantial independence in energy supplies by the mid-1980s would require a determined research effort to develop stack gas cleaning technology for high-sulphur coal. There are indications that a reliable technology could be available, though at a considerable cost.

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Resources of low-cost uranium may well be much larger than we have been led to believe by the U.S. Atomic Energy Commission figures. In any event uranium costs are such a small portion of the cost of nuclear power that the need to go to higher-cost uranium resources would not be economically disastrous to nuclear energy prospects.

It does not appear that such new technologies as coal gasification, coal liquefaction, the breeder reactor, solar energy, geothermal energy, or fusion energy will make a major contribution to commercial energy supplies before the 1990s at the earliest. For the great bulk of domestic production the U.S. will have to continue to depend on oil, natural gas, coal used as coal, and conventional reactor types – assuming their problems can be solved.

The new source and technology which is perhaps most likely to make a contribution to domestic supply within the next several decades is shale oil. Vast resources of oil shale are available in the United States to satisfy liquid-fuels demands for a very long period of time. (High-quality resources are judged of the same order of magnitude as total proved oil reserves in the Middle East.) Production costs of oil from shale cannot be known with certainty because nothing even close to a commercial-scale plant has yet been built. However, based upon extrapolation of data from small experimental plants, it appears that oil from shale could be produced in commercial plants at a cost of about \$28 to \$31/m³. This would result in delivered prices at East Coast consuming centres of around \$35 to \$38/m³.

This is a highly significant figure because, by reason of the very large domestic resource base of oil shale it sets an upper limit on the long-run cost of liquid fuels in the United States. Even if resource grade were to decline somewhat, the resulting cost-increasing pressures would likely be offset by the cost-reducing effects of improvements in the technology of extracting and processing the materials. The rate at which major crude-oil-exporting countries are increasing their prices suggests that the cost to the United States of imported crude oil clearly is heading towards levels that would make shale oil competitive.

Shale-oil production, it should however be noted, causes severe environmental problems. This may result in substantial delays in starting a commercial shale industry while ways are sought to overcome its environmental drawbacks – mainly, how to dispose of spent rock. It is worth noting that this would be the third occasion that serious consideration has been given to developing shale oil into a commercial source in the U.S. There was talk of a shale-oil industry in the 1920s and again after World War II when a modest research and development effort was launched by the government. Each time, new supplies of crude oil dimmed shale oil prospects.

Indeed, this could happen again, for it appears from the R.f.F. analysis that crude oil and natural gas may actually constitute lower-cost means for enlarging domestic supply than would oil shale. While it is unlikely that shale could make a quantitatively significant contribution to U.S. energy supplies during the next decade, there *are* encouraging prospects for the expansion of domestic crude oil and natural gas supply. Domestic natural gas offers probably the lowest-cost option for increasing domestic energy supplies and, therefore, reducing U.S. dependence on imported oil between now and the mid-1980s.

Supply difficulties in natural gas have been a basic cause of the overall energy supply problems now being experienced in the United States. U.S. government policies, now undergoing modifications, have severely limited the rise of gas prices; a severe ensuing shortage of natural gas has been aggravated by the stimulus to gas demand resulting from its attractive characteristics from an environmental standpoint. As gas supplies languished, other fuels,

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particularly oil, were diverted to markets that gas would otherwise have served, leading to supply shortfalls all along the line (abetted, as noted above, by supply-restricting influences that were also affecting other fuels).

Possibilities for a substantial expansion of crude oil output at costs below those of shale oil are also indicated in the R.f.F. supply analysis. If our tentative findings are correct, it would thus appear that growth of both crude oil and natural gas production could lead to an expanded domestic supply capability in the United States, at costs ranging, say, between \$31 and \$38/m³ of oil (or its equivalent), delivered East Coast, and expressed in today's prices.

Moreover, these prices may well be below imported costs for Persian Gulf crude – a remarkable turnabout from conditions that have prevailed during recent years, brought on by the pricing policies now being enforced by the exporting countries. Even if these expectations with respect to conventional hydrocarbons do not materialize, ample supplies of shale oil eventually could be made available, though not without a substantial transitional degree of import dependence.

Our summary view for the United States, then, is that although the period of very low-cost energy is over, we are optimistic that long-term domestic energy prices need not increase nearly as sharply as sometimes predicted, give a favourable economic and environmental policy setting. Measured in constant 1972 dollars the R.f.F. analysis indicates that the nation can produce 80 % of its oil and natural gas requirements in 1985 at crude-oil prices not higher than \$38/m³ and at natural gas prices in the \$21–25/10^3 m³ range. Although a \$38 crude-oil price is twice the level of a few years back, it is still very low in light of the rate at which prices now seem to be increasing.

It should be noted that the stipulated degree of self-sufficiency rests on the expectation that a large expansion of U.S. natural-gas output will moderate total U.S. oil requirements to a level considerably below the consumption that is projected in the standard view high-import situation. Specifically, a reduction to 20 % import dependence in oil is assumed achievable at a 3.18×10^6 m³/day level of oil demand rather than the 4×10^6 m³/day level indicated in table 11. Also, the U.S. self-sufficiency alternative presupposes a capability to produce close to 950×10^6 tonnes of coal in 1985, compared to 600×10^6 t in 1972.

The price and quantity estimates which we have cited for future oil and gas are of course uncertain and should not be taken as predictions of the future. While we believe that the nation's resource position is good and that the basic economics of expanded domestic output are acceptable, much depends on the nation adopting the policies necessary to lead to these results on the schedule we have assumed.

A word about Western Europe's options

Despite the strong historical position of coal in Western Europe, it appears that the most favourable prospects for significantly reducing the European level of import dependence exist, not through use of coal, but through domestic crude oil and natural gas, of which major deposits have been found only in the recent past.

An exceedingly optimistic appraisal of Western European indigenous energy has recently been developed by Professor Peter Odell.† We are in no position to subject his views to critical scrutiny but record them here because (1) they reflect the judgement of a well-qualified analyst,

† Peter Odell 1973 'Indigenous Oil and Gas in Western Europe', *Energy Policy*, **1**, 49.

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and (2) they probably indicate the maximum degree of energy self-sufficiency achievable by the mid-1980s. Coupled with the R.f.F. assessment of options available to the United States, Odell's figures can thus be used to weigh the prospects for a more balanced economic relationship between the major oil exporting and importing nations. Professor Odell perceives production possibilities of indigenous oil and gas production equal to 45 % of total West European energy consumption in 1985, compared to a standard projection of about an 18 % share for the two fuels combined. For oil alone, the high alternative of a 50 % indigenous share compares with the standard projection of around 15 %.

Odell's analysis, based on a comprehensive review of the available information, leads him to the conclusion that the prospects for indigenous supplies in Western Europe have been systematically and substantially underestimated by others. Most European observers, on the other hand, feel that Professor Odell's estimates are two high. Although we are, as indicated, in no position to evaluate the validity of the figures, strictly from a physical point of view such levels of output are achievable.

Concluding remarks

It would be piling conjecture on top of conjecture to judge how the supply alternatives which we have sketched might erode the economic leverage otherwise accruing to the major Eastern Hemisphere exporters.

If the domestic supply possibilities for the United States and Western Europe referred to above were realized, international oil flows in 1985 might look quite different:

Estimated net import requirements in 1985

	standard view		alternative view	
	10^6 m^3/day	10^6 barrels/day	10^6 m^3/day	10^6 barrels/day
United States	2.15	13.5	0.83	5.2†
Western Europe	3.86	24.3	1.65	10.4‡
Japan	2.32	14.6	2.32	14.6
total	8.33	52.4	4.80	30.2

† At 20 % of estimated consumption, the import level of the late 1960s.
‡ Calculated from Odell (1973).

It seems safe to say that if evidence were to emerge that international oil flows could be this strongly affected over the next decade, substantial pressures might be exerted on the economic behaviour of the oil exporting countries. This might be so even if the above estimates of either the U.S. or the West European supply alternative, or perhaps both, are somewhat on the high side.

It is well known that Middle East and North African oil is sold at a large and growing margin over its real costs of production. Under such circumstances, if competition among exporters were for any reason to erupt – as some Western observers think may follow in the wake of greatly increased amounts of 'country-owned' oil entering world markets – these countries would be able to substantially cut their greatly inflated prices if they wanted to carve out a larger share of world markets for themselves. Today, however, there seems little likelihood that competition among the exporting countries will ever return.

But consider that while the real incremental production cost may constitute the theoretical floor to Middle Eastern oil prices, the ceiling to these prices will be determined by conventional or non-conventional energy sources available elsewhere in the world in ample amounts. We have seen how both incremental U.S. crude and shale oil are estimated at real long-term supply costs probably no higher than $\$38/m^3$ in 1972 dollars. With successive increases in Persian Gulf posted prices (the most recent in October, 1973), it will not take many additional increases for the delivered price to approach the ceiling set by the long-run cost of Western Hemisphere alternatives. Conditions thus seem to be developing which could, in time, reintroduce a note of economic reality in the pricing of crude from the Middle East.

This is a potential but not inexorable scenario, which will in any case take time to have visible effect. It does seem to offer one tangible opportunity to gradually provide a viable counter force, though not a hostile one, in international oil markets. We believe that the most pressing policy need is for the United States to embark on a coherent strategy greatly to expand its domestic productive capabilities. Such a strategy – designed to reduce excessive external dependence – seems now to be gathering increasingly widespread support in the United States, the more so in the wake of the latest developments in the Middle East. This is a policy which is clearly not a reversion to narrow economic nationalism. Indeed, it is an internationally forward-looking policy, in that it promises to blunt the enormous economic advantage exercised by the major exporters over countries – both developed and less developed – which inevitably will remain measurably dependent on substantial amounts of imported energy for many years to come. It would also make less likely a fiercely competitive scramble among buyers seeking to assure themselves of supply adequacy, with all the destabilizing international political and economic effects that this would imply. It promises, finally, to reduce the scope for international monetary disruption which a continued unilateral advantage in international oil bargaining would otherwise confer. The lines of development we have indicated offer hope that the instability which presently characterizes world oil flows, and which is bound to be with us for some time into the future, is none the less a course from which the world can yet break loose.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES