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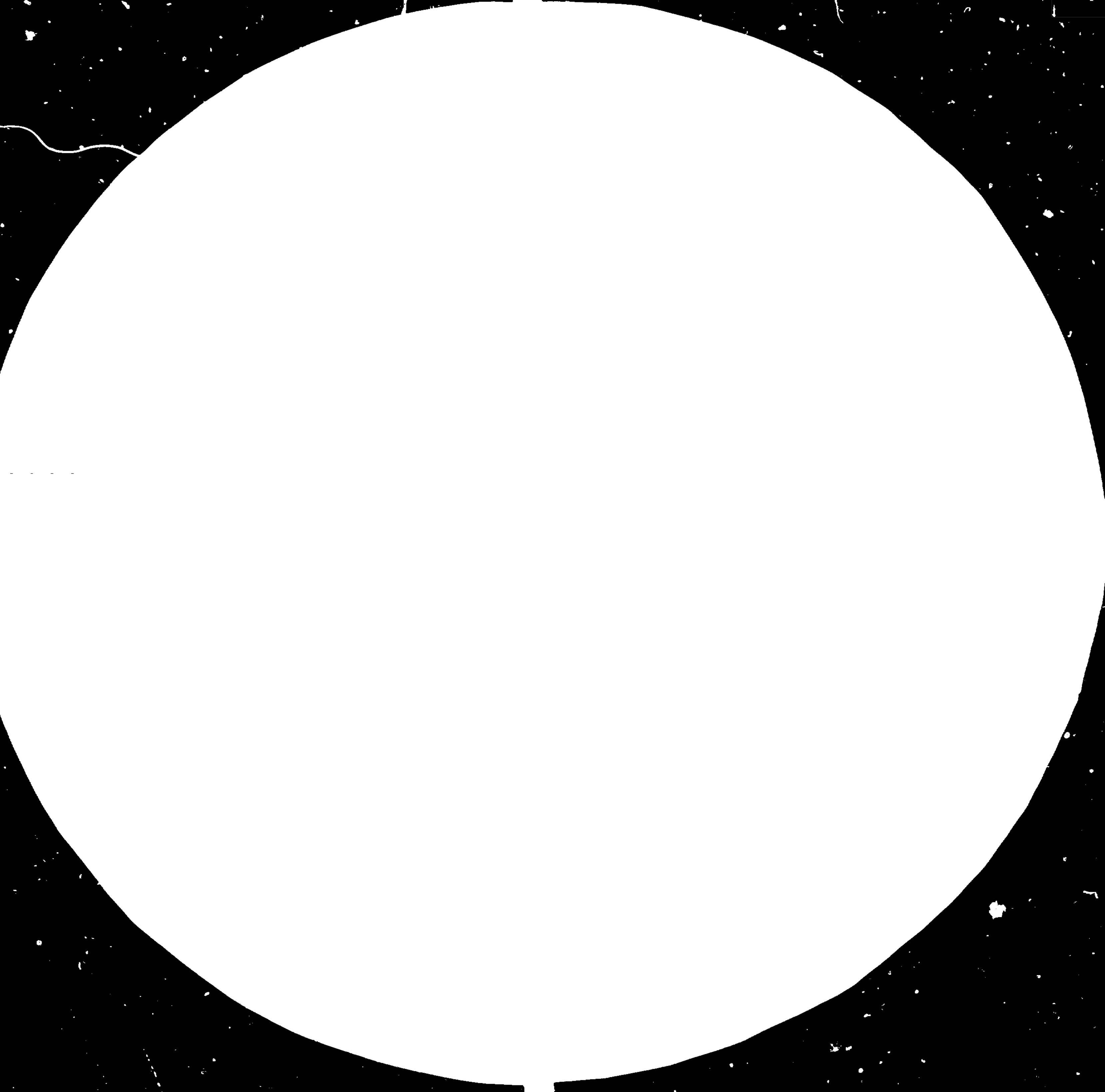
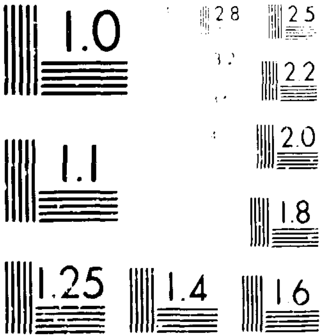




MICROCOPY RESOLUTION TEST CHART

THE DIMENSIONS OF ENERGY REQUIREMENTS AND THE LIMA TARGET

prepared by the

Global and Conceptual Studies Section

International Centre for Industrial Studies

to be submitted to the

Working Group of the

Committee for Development Planning

December 1978

One thing is now clear to us all: the problem of the developing countries and the growth disparities between the industrialized and non-industrialized parts of the world. The whole of this third world is determined to draw level, in some respects at least, with the industrialized world. However, in order to understand the law of motion of economic development, in general, and the motives behind industrialization efforts, in particular, we have to understand human nature and the manner in which it reacts to the various kinds of social, political and economic systems in which it has to operate. This is the characteristic feature of the spirit with which the Lima Declaration and Plan of Action is imbued. This study, which intends to investigate the feasibility of achieving the target set therein focuses attention on the dimensions of the world demand for, and supply of energy, and calls for a proper plan of action to ensure its implementation.

If we consider just a few salient features of the developing countries (excluding centrally-planned Asia), in 1970, their total population was 1.7 billion; the average GNP per capita was $270; and the per capita consumption of energy was less than .31 tonnes of coal equivalent per year. Historically though, the energy sector of certain developing countries, was supposedly the most developed sector, financed by capital from developed countries. However, its impact on other sectors of the economy, which would have contributed to development process, has been minimal. Considering the present aspirations to industrialization and economic development, it is quite understandable, that these features are bound to change by the year 2000. If this be so, the people in this category of countries, having secured 25 per cent share of total world industrial output, would have achieved a standard of living normally associated with a stage of economic development requiring 1.7 tonnes of coal equivalent energy consumption per head. Be that as it may, an increasing amount of energy would be required for the accelerated process of industrialization and economic development. However, the development of the energy sector as such would require large investment resources, and these are in short supply for most of the non-OPEC developing countries.

Since the so-called energy crises in 1973, tremendous efforts have been made to evaluate the gravity of the situation. There are, of course, various studies pertaining to the consumption pattern of energy. A recent econometric study at IIASA, using the data from seven selected developed countries, concludes that the population, per capita income, and relative price of the energy are the main variables determining total consumption. It is claimed that the explanatory power of these determining factors is about 95 to 99 per cent. Although this study does take into consideration the notion of derived demand for energy from the interrelations among production, technology and consumption preferences - and this might well be relevant for the short term forecasting - it falls rather short of the very essence of the dynamic aspect of the problem. It fails, so to speak, to describe the law of motion of an economy in the new context of a closer global interdependence. In considering the time horizon and its extension, it is necessary to incorporate changes in the values of the relevant parameters which characterize the structure of models. A typical example of a long-term forecasting model is found in the recently published study of the Leontief model. This model forecasts energy demand using projected input-output coefficients which are based on the consideration of technological development, formation of relative price of materials, and the essence of dynamics in competitive substitution. On the basis of the parameters given in the Leontief report, a preliminary result for the energy requirements of the Lima target, has been summarized in Table 1. According to our standard reference Lima scenario, the total energy requirements for the world in the year 2000 would be in the order of magnitude of 24,701 MTCE, of which 26.7 per cent (6,599 MTCE) would be required for the developing countries in their efforts to achieve the Lima target.

Most of the other existing global energy projections assume rather lower economic growth rates. The result of a composite forecast, combining OECD, WAES, EDP, CIA and others, is given in Table 2. It indicates the total world energy demand in the year 2000 as 21,000 MTCE, and the projected share of the developing countries is approximately 19.3 per cent (4,050 MTCE).

TABLE 1

Developed Region (Lima share = 7%)

	1970		1980		1985		1990		2000	
GDP (billion $)	2723.90	(4.3)	4162.16	(4.4)	5157.55	(4.4)	6383.78	(3.3)	8831.77	(4.0)
Population (million)	1108.30	(1.0)	1220.51	(0.9)	1278.21	(0.9)	1338.42	(0.8)	1445.91	(0.9)
GDP/Per capita ($)	2456.42	(3.3)	3401.01	(3.5)	4035.48	(3.5)	4771.04	(2.5)	6110.36	(3.1)
Total Manuf. V.A. (billion $)	586.35	(4.1)	879.73	(4.2)	1079.07	(4.3)	1332.00	(3.3)	1835.83	(3.9)
Energy Requirements										
Million tonnes coal equivalent	5592	(4.47)	8658	(3.66)	10361	(4.30)	12791	(3.53)	18102	(3.99)

Latin America (Lima share = 13%)

	1970		1980		1985		1990		2000	
GDP (billion $)	153.60	(6.5)	289.69	(8.6)	437.04	(8.6)	660.16	(9.8)	1684.97	(8.3)
Population (million)	281.40	(2.8)	371.24	(2.7)	425.11	(2.7)	486.68	(2.5)	623.77	(2.7)
GDP/Per capita ($)	545.71	(3.7)	780.56	(5.9)	1030.31	(5.9)	1361.95	(7.3)	2719.28	(5.6)
Total Manuf. V.A. (billion $)	21.38	(7.4)	43.80	(9.1)	67.74	(9.2)	105.33	(11.7)	318.33	(9.4)
Requirements										
Million tonnes coal equivalent	223	(7.46)	458	(8.94)	703	(8.38)	1051	(8.47)	2369	(8.20)

Middle East (Lima share = 3%)

	1970		1980		1985		1990		2000	
GDP (billion $)	32.21	(11.0)	102.82	(7.0)	144.33	(6.9)	201.96	(5.8)	353.31	(7.9)
Population (million)	126.50	(3.1)	171.75	(3.3)	201.60	(3.3)	236.57	(3.1)	322.02	(3.2)
GDP/Per capita ($)	286.00	(7.9)	567.51	(3.7)	700.82	(3.6)	860.99	(7.7)	1085.67	(4.7)
Total Manuf. V.A. (billion $)	12.14	(19.3)	13.03	(9.1)	20.18	(9.8)	32.20	(8.6)	73.56	(12.5)
Energy Requirements										
Million tonnes coal equivalent	82	(13.77)	298	(9.68)	473	(7.59)	682	(5.29)	1142	(9.18)

(Figures in brackets represent the Annual Growth Rate - Percentage)

Asia (Lima share = 7%)

	1970	1980	1985	1990	2000
GDP (billion $)	122.60 (6.8)	236.32 (8.7)	358.83 (8.7)	544.75 (8.4)	1224.49 (8.0)
Population (million)	1023.20 (2.6)	1328.13 (2.6)	1510.47 (2.6)	1717.52 (2.3)	2160.94 (2.5)
GDP/per capita ($)	119.00 (4.2)	176.92 (6.1)	236.86 (6.1)	317.10 (6.1)	567.75 (5.5)
Total Manuf. V.A. (billion $)	14.08 (6.6)	26.67 (10.0)	42.89 (10.3)	70.08 (9.4)	171.36 (8.7)
Energy Requirements					
Million tonnes coal equivalent	178 (9.69)	449 (9.54)	708 (10.23)	1152 (8.59)	2626 (9.39)

Africa (Lima share = 2%)

	1970	1980	1985	1990	2000
GDP (billion $)	50.60 (6.2)	92.60 (7.4)	132.18 (7.4)	188.75 (8.5)	427.87 (7.4)
Population (million)	272.60 (2.8)	357.73 (3.0)	414.28 (3.0)	479.75 (2.9)	640.40 (2.9)
GDP/per capita ($)	185.29 (3.4)	259.17 (4.4)	322.05 (4.4)	400.29 (5.6)	680.49 (4.5)
Total Manuf. V.A. (billion $)	4.78 (5.9)	8.47 (9.5)	13.34 (10.7)	22.13 (8.3)	48.96 (8.1)
Energy Requirements					
Million tonnes coal equivalent	52 (7.18)	104 (6.87)	145 (9.47)	228 (7.32)	462 (7.55)

(Figures in brackets represent the Annual Growth Rate - Percentage)

TABLE 2

	1975	2000	Growth Rate %
Developed countries	5,175 (58.6%)	10,200 (48.6%)	2.75
Developing countries	1,050 (11.9%)	4,050 (19.3%)	5.5
Centrally planned countries	2,610 (29.5%)	6.750 (32.1%)	3.9
World Total, 10^6 TCE	8.835 (100%)	21,000 (100%)	3.55

In considering, therefore, the energy dimension of the Lima target, the next inevitable question is whether the requisite amount of energy could be supplied. The current consensus is that the world supplies of petroleum are not sufficient enough to meet world requirements through 1990. It is, however, believed that insofar as technological progress and resources are concerned, several options do exist for an adequate supply of energy. Of course, this does not necessarily insure against regional shortages and high prices, nor does it guarantee smooth transition when the world is forced to adopt a new energy option in the near future.

In view of the above facts, an assessment can be made of the plausibility of the global oil shortage that might occur in achieving the Lima target. But it should be recalled that oil belongs to the category of exhaustible resources and, such being the case, its optimal utilization is called for. Furthermore, the high growth rate of world GDP over the next decade or so implied in the Lima target might well cause a serious oil shortage before a satisfactory solution can be found to ease the transition. If this be so, the implementation of the Lima target might be in jeopardy. It should, however, be observed that the Lima target, which has been set in terms of relative share, does not presuppose a high absolute growth rate of world GDP. In fact, this target could be achieved at one per cent world growth rate of GDP, provided all the growth occurs in the developing countries, which would be 3.8 per cent per annum.[1/] The latest consensus is, however, that although economic recovery might still take a long time, the average for the developed countries for the next two decades would be 4 per cent per annum. This is the basic figure that has been used at UNIDO pertaining to Lima reference scenario.

1/ The Lima targets imply roughly 5.5 per cent higher growth rate in manufacturing value-added for the developing countries than the growth rate in the developed countries. Since the growth rate in the manufacturing sector is expected to be faster than the GDP growth rate itself in the developing countries (the Lima scenario assumes a 1.3 to 1 ratio), while the manufacturing sector in the developed countries will keep pace with the rest of the economy, it takes roughly 4 per cent GDP growth rate difference to achieve the Lima target. These calculations are based on the 1970 figures as the base year figures (in order to conform with the Leontief study) and thus exclude centrally-planned Asia.

However, in order to evaluate the situation, three alternative scenarios will be considered:

i) High Growth (HG) Lima Standard Reference Scenario
GDP growth rates for (a) developed countries: 4.0 per cent; (b) developing countries: 8.0 per cent; and (c) world: 4.8 per cent. This in turn implies 4.7 per cent annual growth rate in the total energy requirements for the world; 4.0 per cent for the developed, and 8.5 per cent for the developing countries. The annual rate of increase in demand for oil is 4.5 per cent.

ii) Low Growth (LG) Scenario
GDP growth rates for (a) developed countries: 2.0 per cent; (b) developing countries: 6.0 per cent; and (c) world: 2.8 per cent. This implies 2.7 per cent annual growth rate in the energy requirement for the world; 2.0 per cent for the developed, and 6.4 per cent for the developing countries. The annual rate of increase in the demand for oil is 2.5 per cent.

iii) No (Net) Growth (NG) Scenario
GDP growth rates for (a) developed countries: 1.0 per cent; (b) developing countries: 5.0 per cent; and (c) world: 1.8 per cent. This implies oil demand growth rate of 1.4 per cent per annum.1/

According to these calculations, it so happens that under the assumption of (HG), the supply of oil would be insufficient even to meet the demand

1/ The income (GDP) elasticities of oil demand used in the original Lima scenario (HG) are: for developed countries, 0.99 (1970-1980), 0.84 (1980-1990), and 0.78 (1990-2000); for the developing countries, 1.14 (1970-1980) and 0.99 (1980-1990) and 0.84 (1990-2000). When computing the oil demands under the Low Growth and No Growth versions, we subjected these elasticity figures to change according to the relative declines in GDP growth rates. In other words, we have forced the propensities to consume oil to decline more than proportionately when GDP growth rates are lowered. As can be seen in the table showing regional oil demand, the income (GDP) elasticity of oil demand in the developed countries under the No Growth Lima scenario becomes 0.5 (1.0 per cent GDP growth induces 0.5 per cent growth in oil demand). This 0.5 elasticity figure has been frequently mentioned under the case of a most stringent energy conservation measure applied in the developed countries.

beyond the year 1995. On the other hand, the potential oil supply is large enough to enable the world to grow at the rate implied in (LG) till the year 2005, and in the case of (NG) it reaches the year 2019.

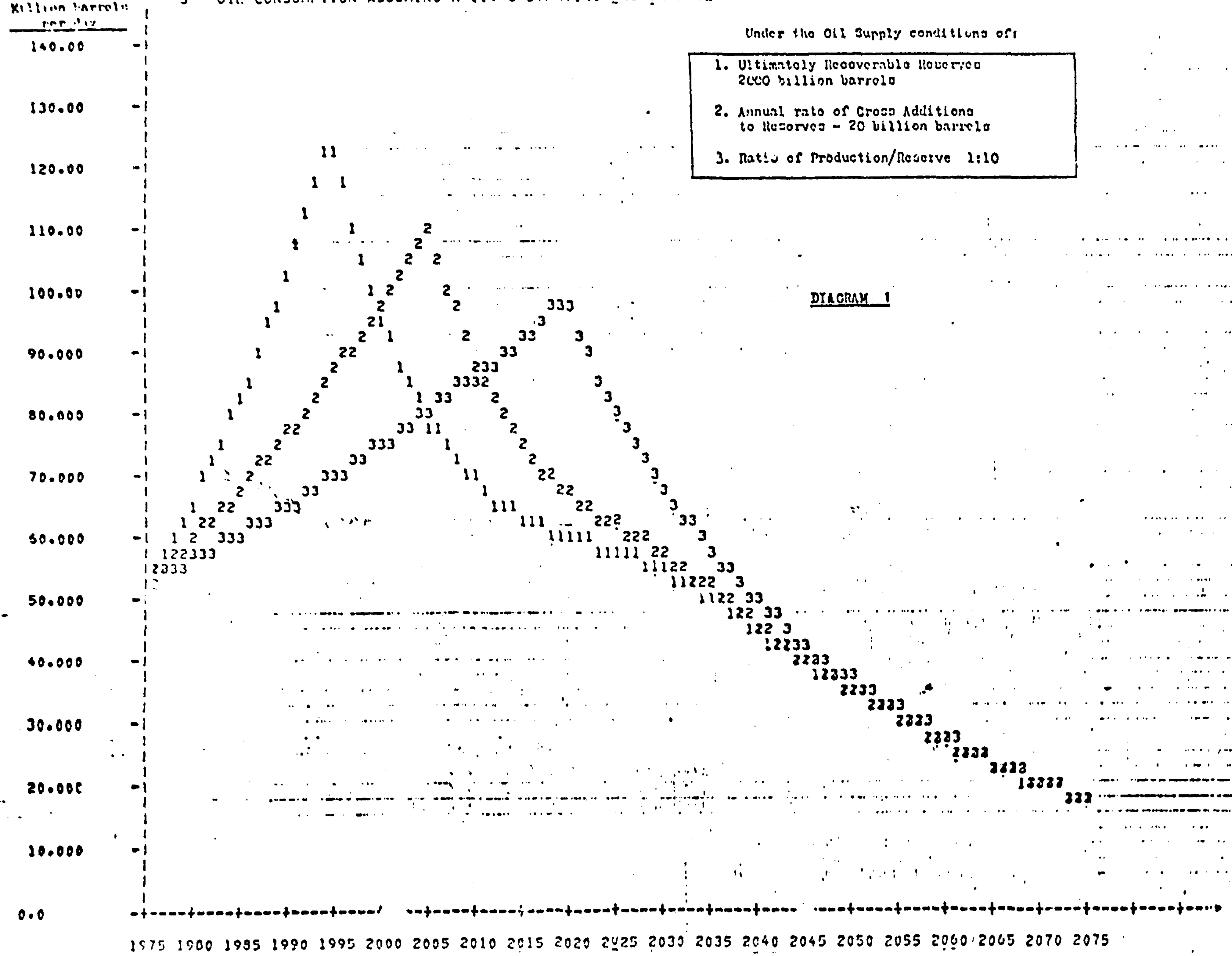
Diagram 1 illustrates these three scenarios. The oil supply schedules as drawn in the diagram are on the assumption that when oil demand is less than maximum potential production, actual production will be equal to the demand (no stockpiling), and when demand exceeds potential production, demand will be limited to this potential which becomes actual production in the absence of any imposed production limit. The line segment showing an upward slope in the initial period represents expanding oil demand before the oil supply constraint becomes binding.

As regards the oil supply, even though we might come to an agreement on the estimate of present oil reserves, the rate of potential production in future would depend very much on the oil discoveries and recovery techniques. The probabilities of such events are unknown. As can be seen in diagrams 2 and 3, the maximum potential annual production computed under the most optimistic conditions (20 billion barrels yearly gross addition; 10:1 reserve to production ratio) is twice as high as the oil supply figures computed under the least favourable conditions (10 billion barrels yearly gross addition; 15:1 reserve to production ratio). Diagram 3, which depicts the future oil supply and demand situations under the low growth scenario, demonstrates the crucial difference (an oil shortage may come in 1992, as distinct foom 2005) resulting from different assumptions regarding the oil supply conditions.

It is true that under the ordinary circumstances it would be rather inconceivable even to consider policy recommendation based on projections with a 50 per cent margin of error, let alone accept them. However, with the real prospects of an oil shortage in the near future, refusal to consider a definite plan of action now is even more inconceivable. Although an analysis is to be made of the implications of different scenarios under all possible combinations of various technical factors determining the future oil supply, the discussion below is based on assumed figures of 15 billion barrels annual gross additions to reserve resulting in a 12:1 reserve/production ratio. (An explanation of the technical factors and method used to compute the future oil supply is attached).

WORLD OIL CONSUMPTION UNDER OPTIMISTIC OIL SUPPLY

1 OIL CONSUMPTION AS NG A 4.5 % STARTING GROWTH RATE
2 OIL CONSUMPTION AS MING A 2.5 % STARTING GROWTH RATE
3 OIL CONSUMPTION ASSUMING A 1.4 % STARTING GROWTH RATE



WORLD OIL SUPPLY AND DEMAN

High Growth Lima Scenario under different oil supply assumptions (See explanation in the text)

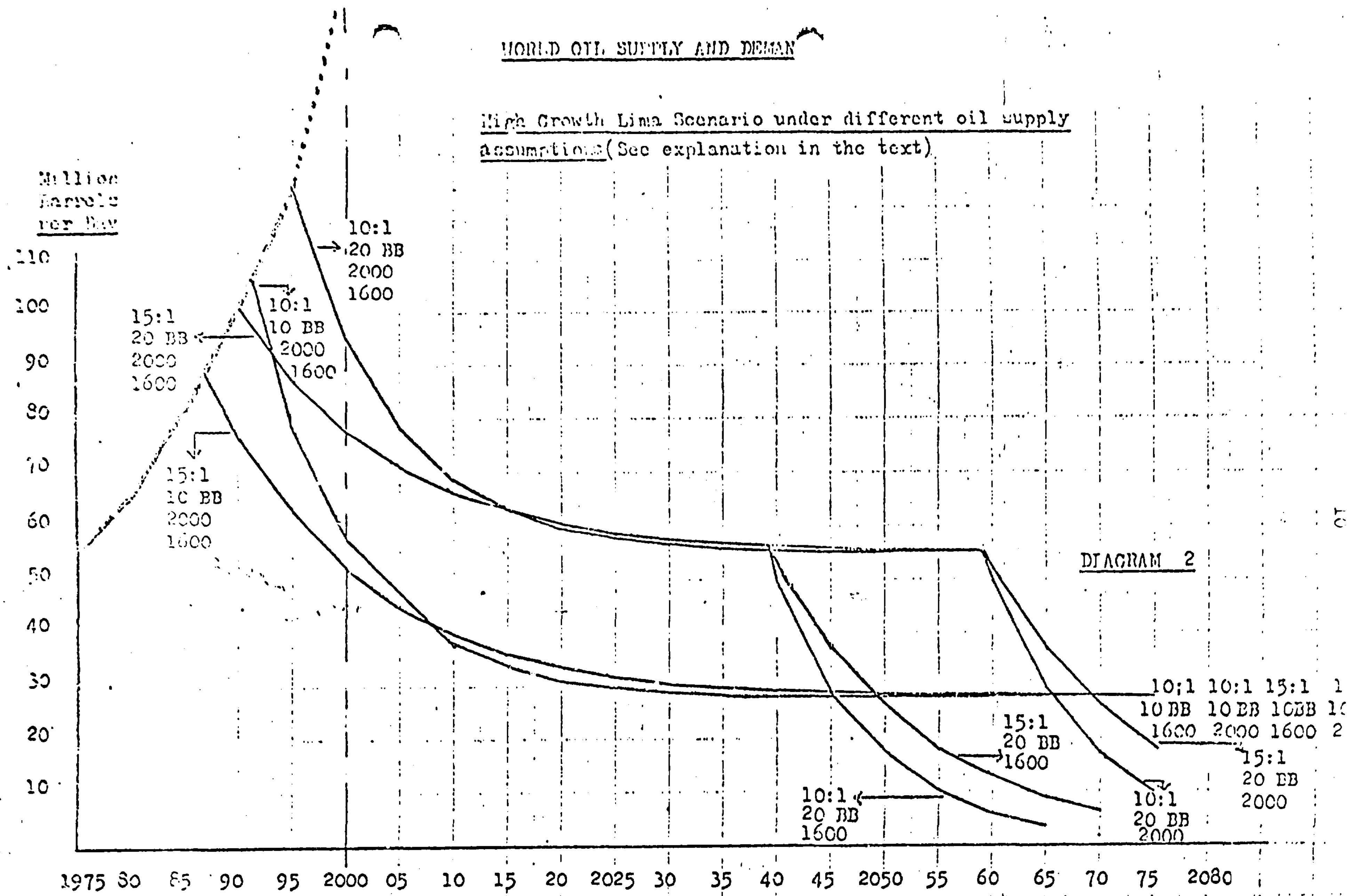


DIAGRAM 2

WORLD OIL SUPPLY AND DEMAND

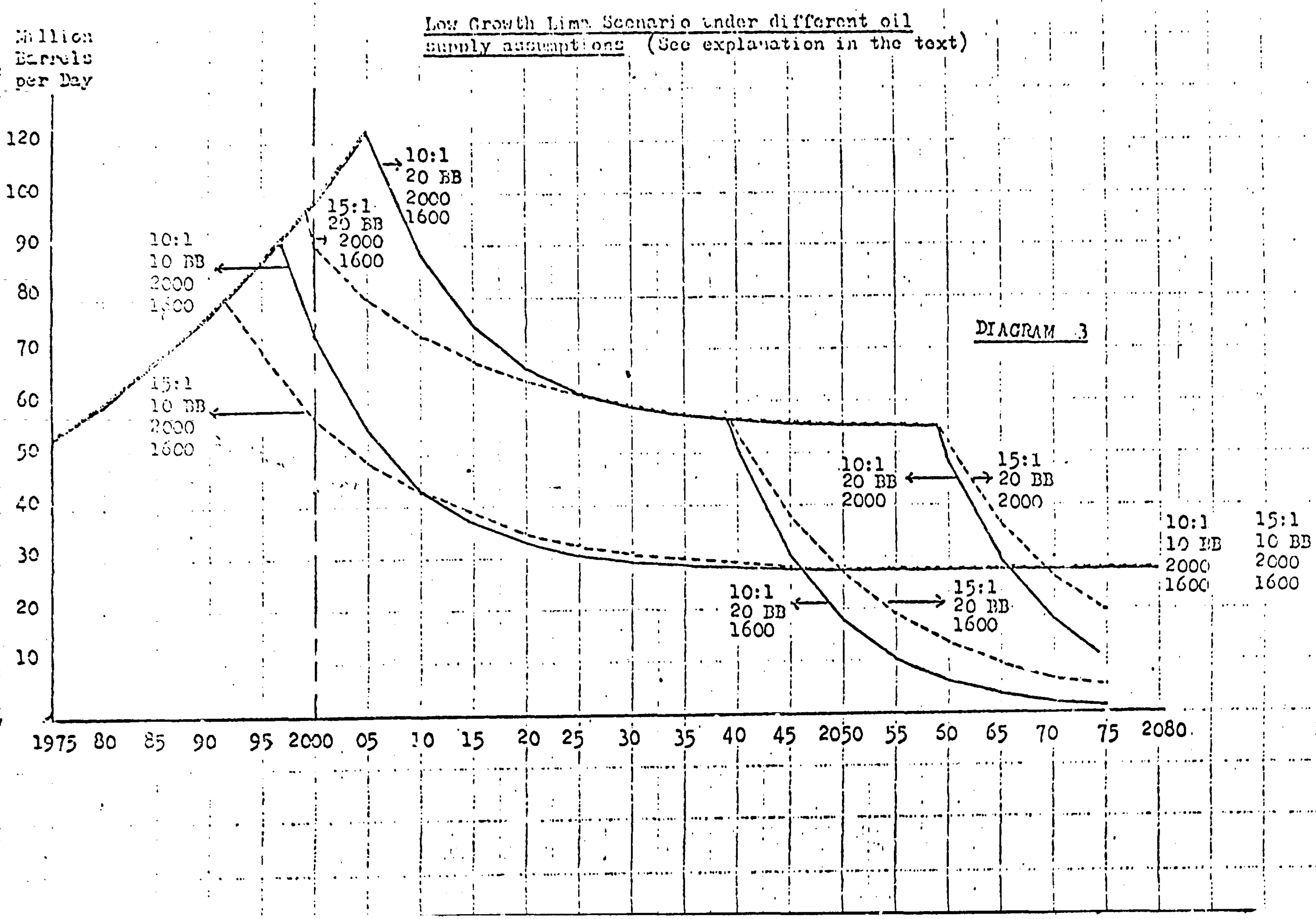


Diagram 4 indicates the results of our calculations. The maximum periods for which the future oil demand can be sustained at the potential annual production rate are 16, 23 and 32 years for High growth, Low growth, and No growth Lima scenarios respectively. Expressed rather drastically, oil will run out before we have progressed two-thirds of the way towards the Lima target. Adopting the Low growth would provide more time, but not beyond the year 1998. Given the future oil supply prospects, the No grwoth scenario alone becomes a feasible proposition.[1/]

Furthermore, diagrams 5, 6 and 7 show the total projected world figures under the three different scenarios to obtain some notion as to the magnitude involved in finding substitute energy sources for oil, and thus providing an indication of the dimensions of the world oil shortage.

As is well known, currently, oil is the preferred source of energy. It meets about 55 per cent of the total primary (commercial) energy requirements of the world. If not constrained by supply, oil is to maintain its leading position and would comprise 50 per cent of the total primary energy until the year 2000 and possibly beyond. However, given the projected size of oil shortfalls under the High growth Lima scenario, energy resources other than oil will have to meet 75 per cent of the toal energy requirements in the year 2000. In fact, the total energy required to replace oil in the year 2000 alone is twice as large as the current (1975) non-oil fuel consumption.

Thus, having given the energy dimensions of the Lima targets, the questions as to the genuine options arise. It is not inconceivable that the supply of energy will increase with the given state of technology and the availability of resources. There are, of course, various options. As a matter of fact, the fixity of resources depends on the nature of technological progress at the particular time. However, certain time-lead is essential in order to determine atlernative energy resources. Moreover,

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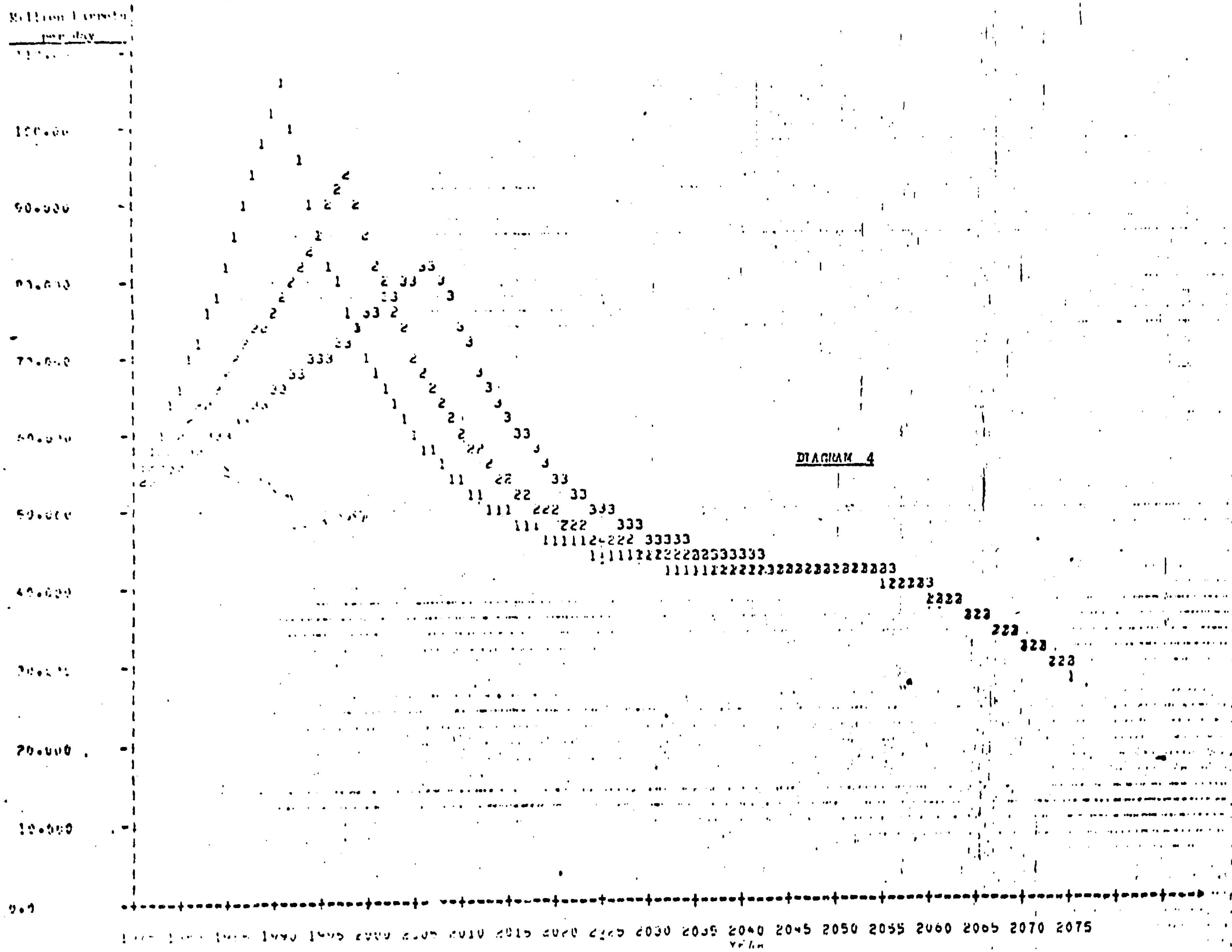
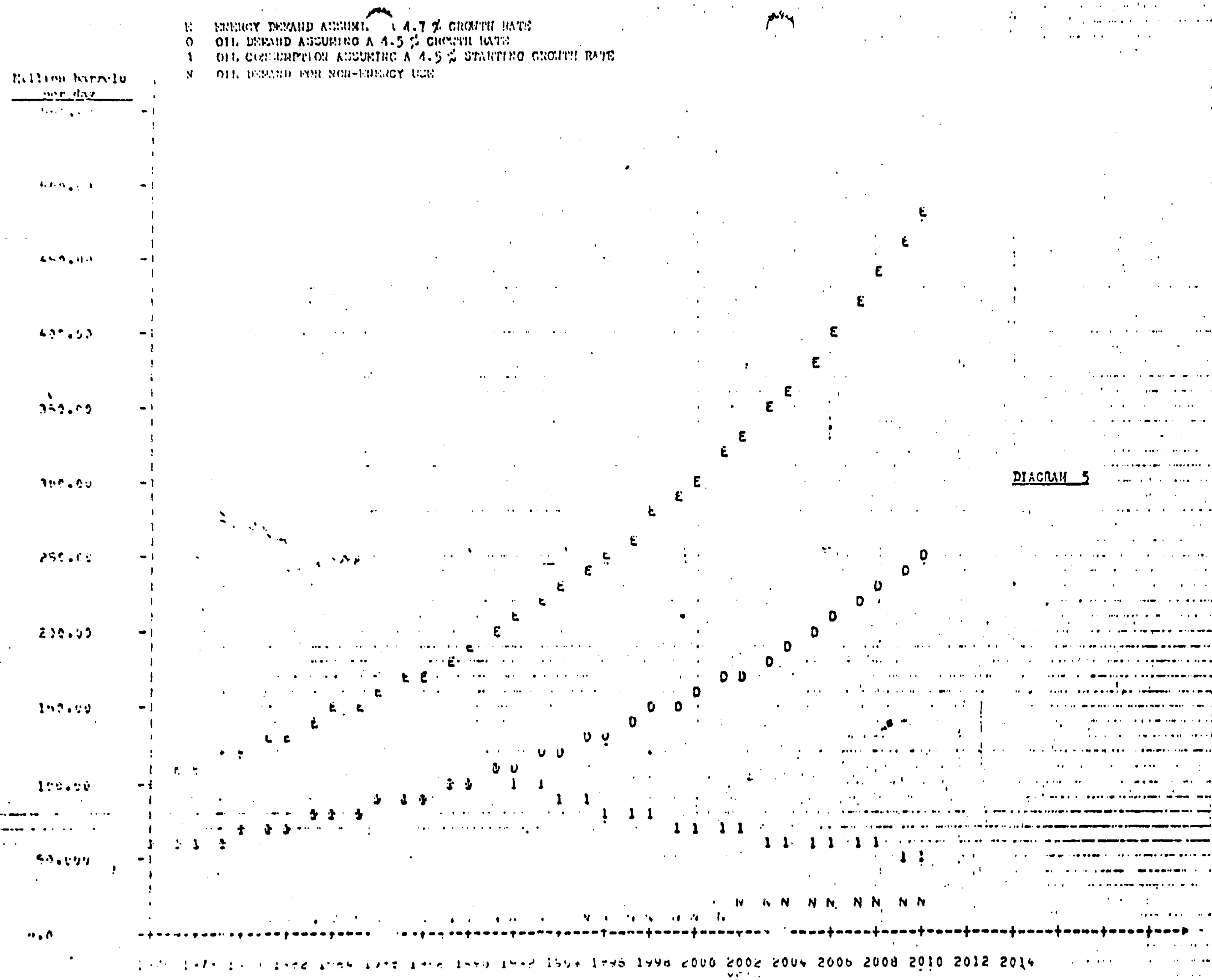
1/ The theoretical growth rate in oil demand which can be sustained until the year 2000 is 2.1 per cent per year. This figure coincides with the projected world population growth rate, and therefore, oil supplied at this rate could guarantee oil consumption per capita at its current level until the year 2000.

WORLD OIL CONSUMPTION UNDER LESS OPTIMISTIC OIL ...





O OIL DEMAND ASSUMING A 4.5 % GROWTH RATE
N OIL DEMAND FOR NON-ENERGY USE
Million barrels per day
1996 2000 2002 2004 2006 2008 2010 2012 2014
DIAGRAM 5

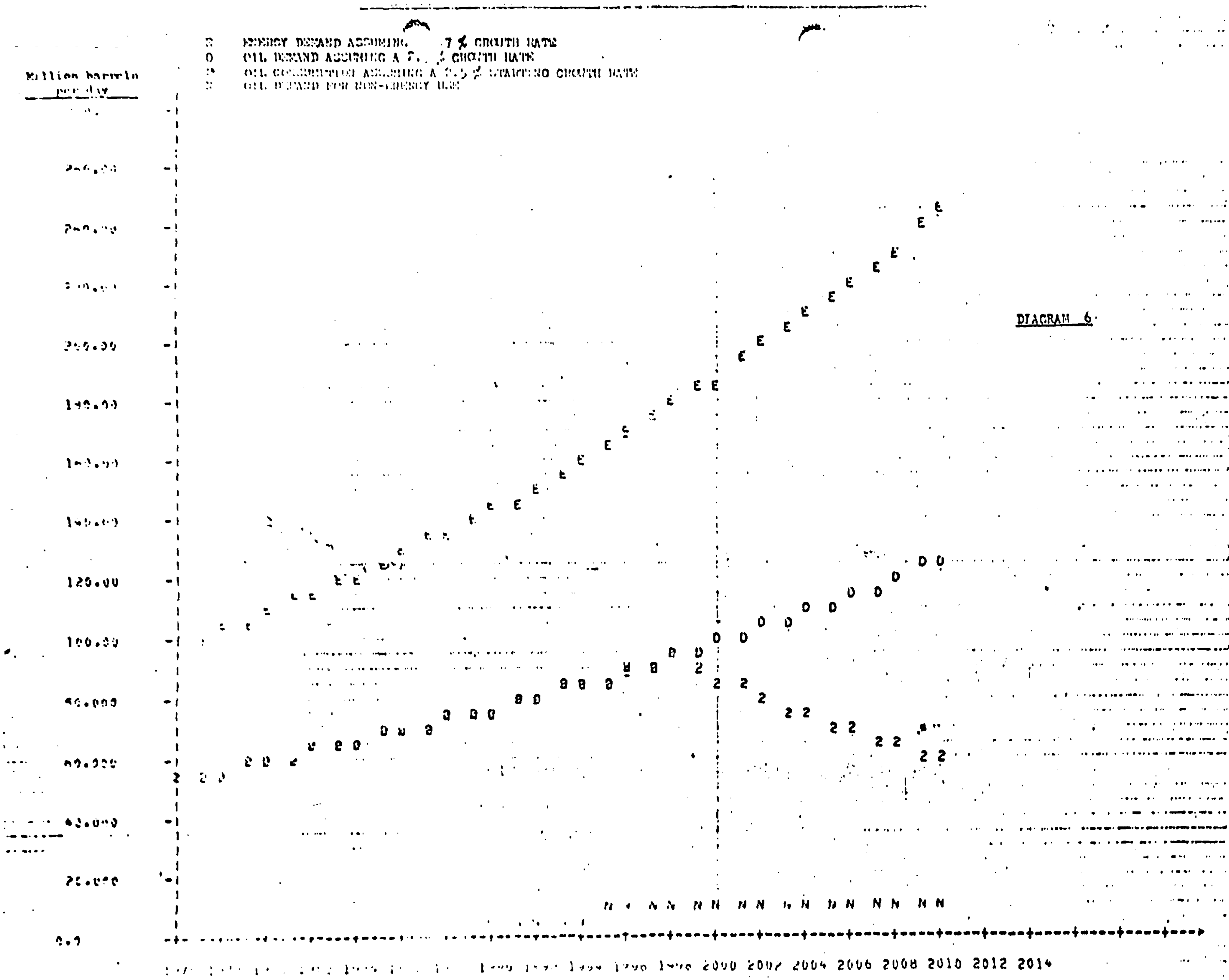
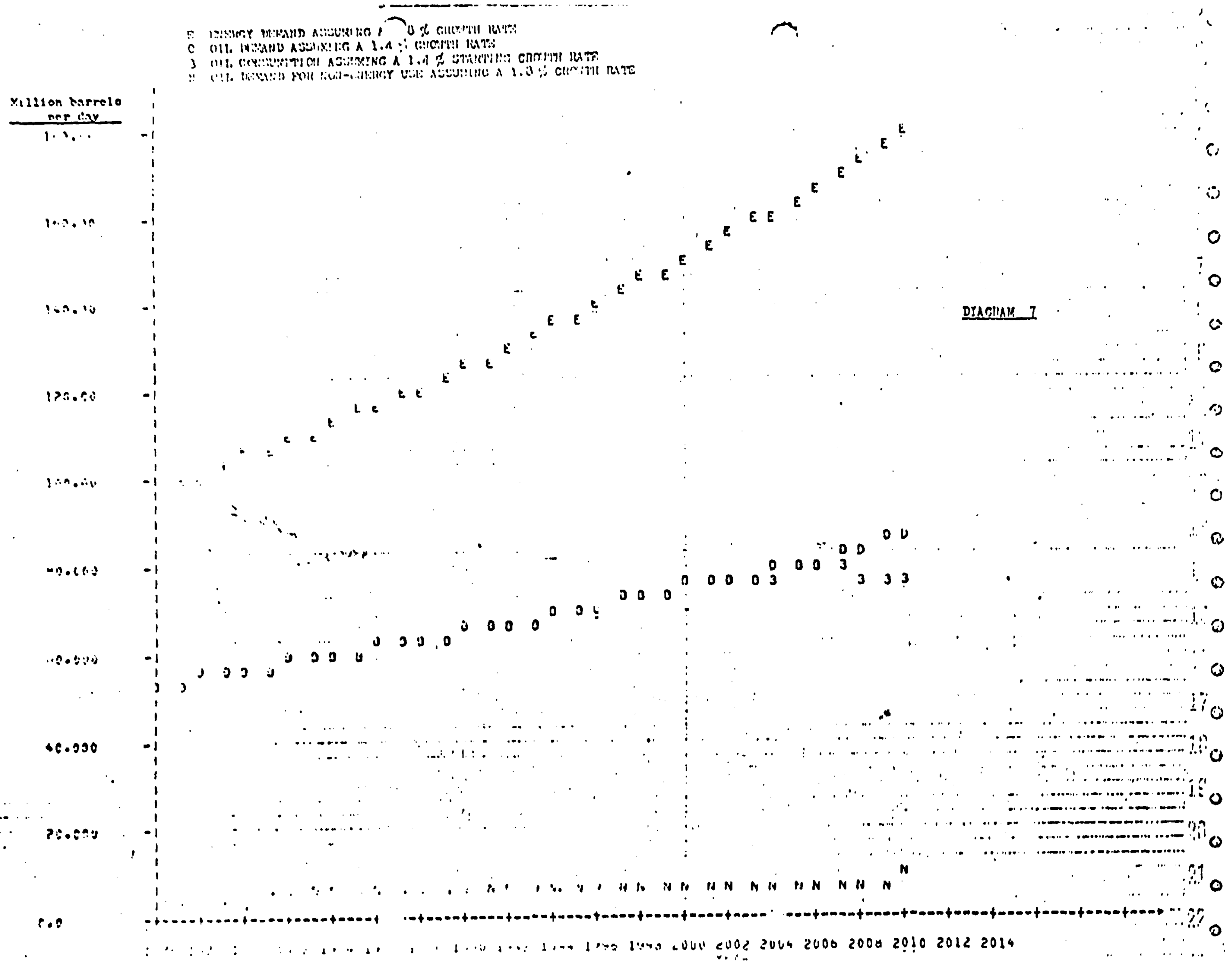

E ENERGY DEMAND ASSUMING .7 % GROWTH RATE
O OIL DEMAND ASSUMING A 7. % GROWTH RATE
OIL CONSUMPTION ASSUMING A 7.5 % STARTING GROWTH RATE
OIL DEMAND FOR NON-ENERGY USE
Million barrels per day
200.00
180.00
160.00
140.00
120.00
100.00
80.000
60.000
40.000
20.000
0.0
2000 2002 2004 2006 2008 2010 2012 2014

DIAGRAM 6

DIAGRAM 7



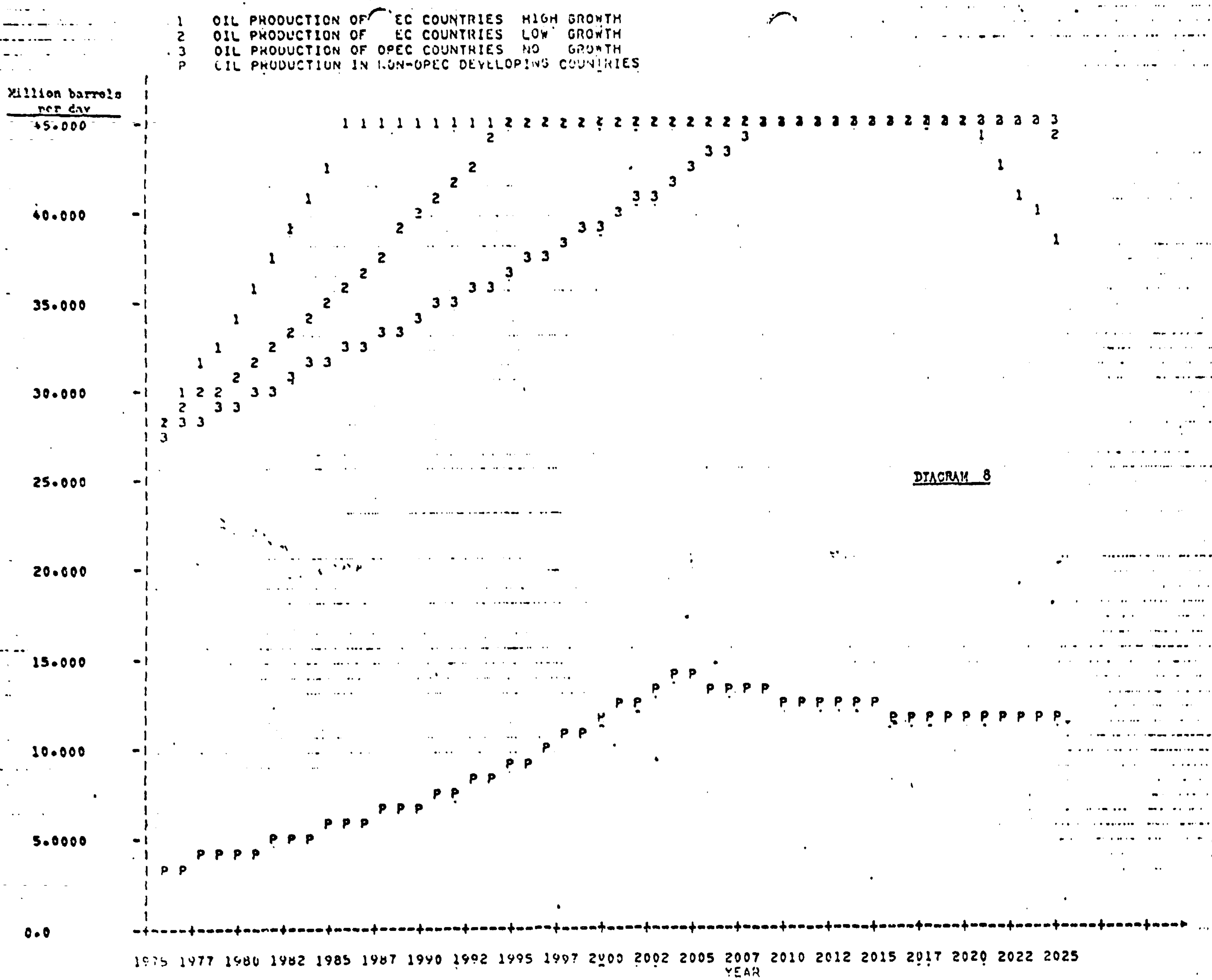
OIL DEMAND ASSUMING A 1.4 % GROWTH RATE
OIL CONSUMPTION ASSUMING A 1.4 % STARTING GROWTH RATE
Million barrels per day
120.00
40.000
20.000
0.0
2002 2004 2006 2008 2010 2012 2014

answering these questions strictly in a global context limits the perspective, although in certain situations consideration on a global scale is inevitable. It has been frequently mentioned that coal and nuclear energy could bridge the world energy gap. Furthermore, solar energy could be of unlimited magnitude.

Coal is abundant, but is very unevenly distributed geographically. Excluding China, only India possesses substantial amounts of coal. Taken together, the developing countries possess less than 5 per cent of the world's known coal reserves. With regard to nuclear power, many people believe that it will substantially alleviate the oil shortage problem, but it does not seem to be a feasible option for the developing countries. Moreover, even for advanced countries, the option is not without hazards; for as yet, it is not proven to be completely safe. Under these circumstances, one might be tempted to explore the possibility of reserving some of the oil which the developing countries produce for their own use.

Diagrams 9, 10 and 11 indicate the total oil supply potential of the developing countries (both OPEC and non-OPEC) fitted against the future oil demand projections under the three scenarios. As stated earlier, the growth in oil demands for the developing countries under these scenarios is quite high (8.1, 6.0 and 4.9 per cent respectively). Moreover, if all the oil produced in the developing countries is reserved for their exclusive use, oil supplies would mee the demand only until the years 2004, 2011 and 2020 under the High growth, Low growth and No growth scenarios respectively. Of course, reserving the oil production of the developing countries for the exclusive use of their development, is impracticable politically and probably undesirable economically.

Thus, an optimum allocation scheme for the limited world oil supply is highly desirable in order to serve the interests of all members of the international community.



1 OIL PRODUCTION OF OPEC COUNTRIES HIGH GROWTH
2 OIL PRODUCTION OF OPEC COUNTRIES LOW GROWTH
3 OIL PRODUCTION OF OPEC COUNTRIES NO GROWTH
P OIL PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES
Million barrels per day
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.0000
0.0
1975 1977 1980 1982 1985 1987 1990 1992 1995 1997 2000 2002 2005 2007 2010 2012 2015 2017 2020 2022 2025
YEAR

DIAGRAM 8

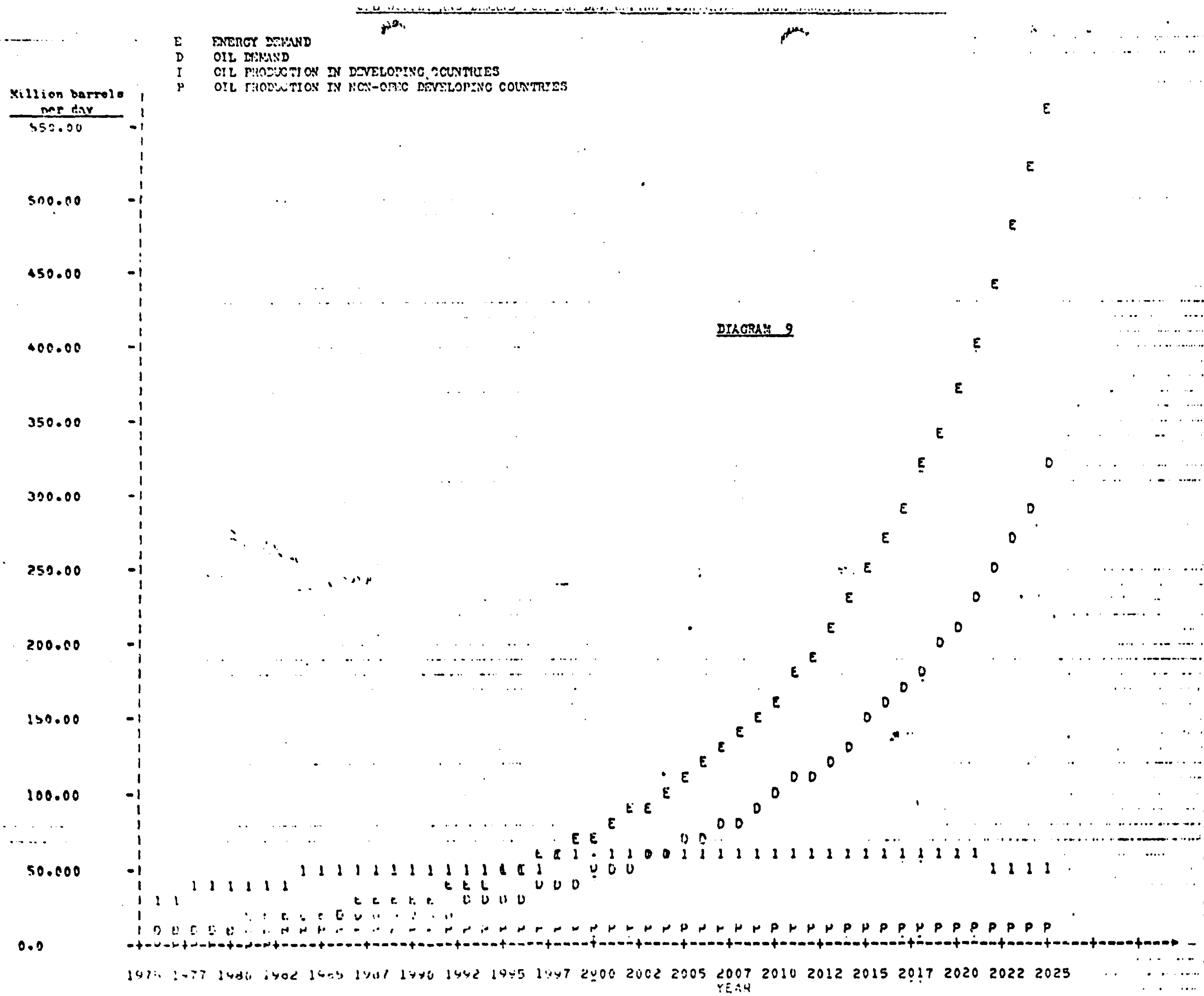
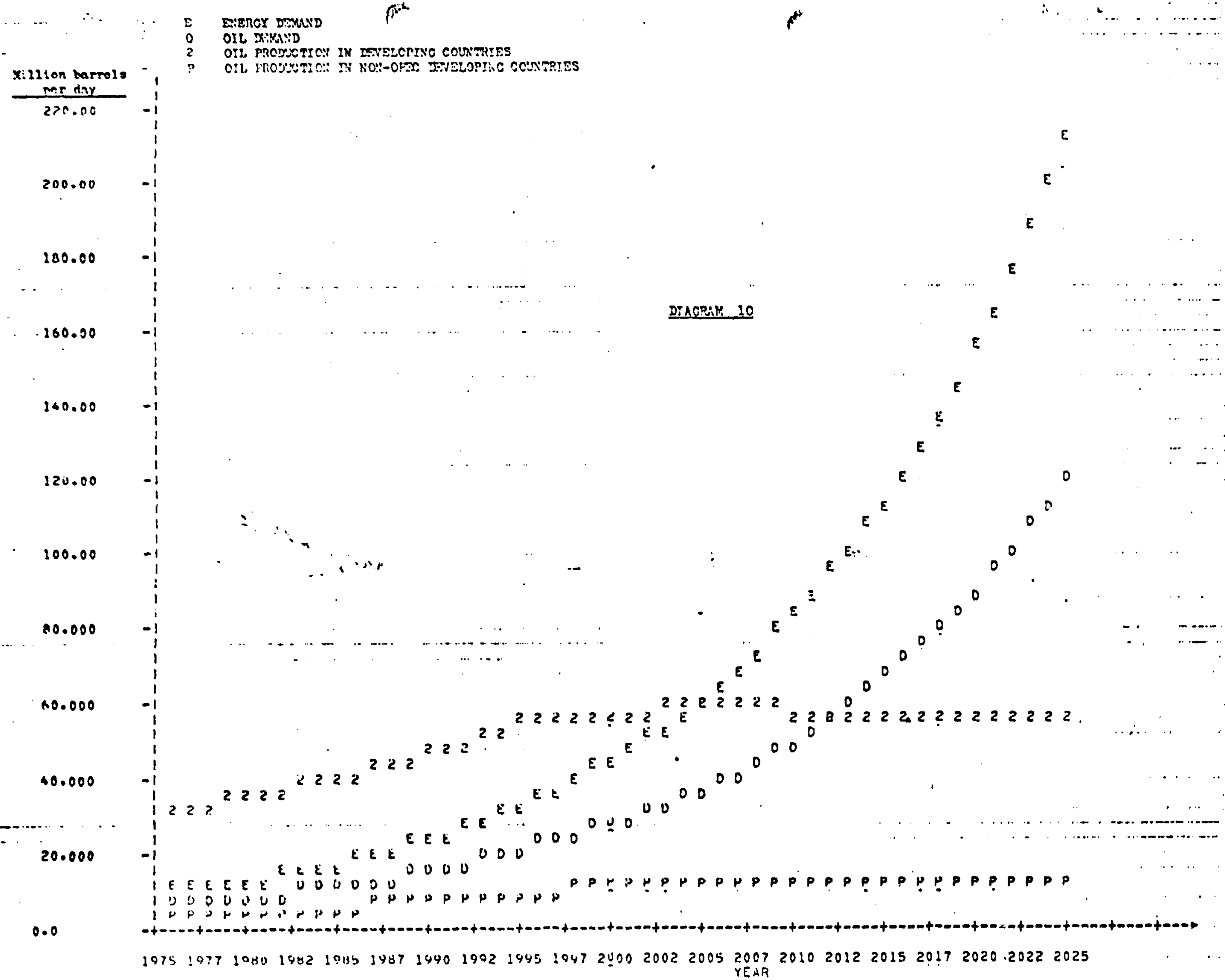
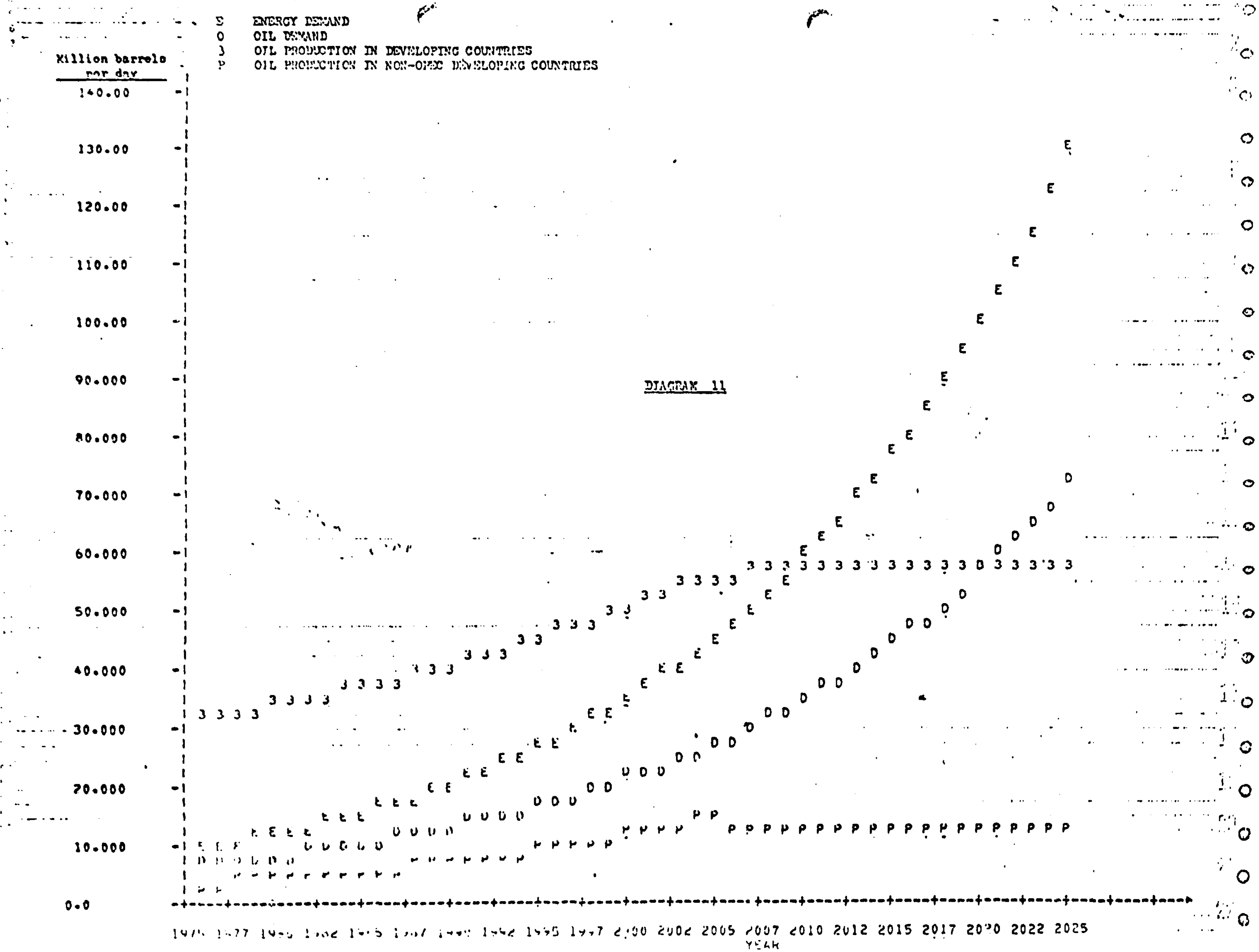

E ENERGY DEMAND
D OIL DEMAND
I OIL PRODUCTION IN DEVELOPING COUNTRIES
P OIL PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES
Million barrels per day
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.000
0.0
DIAGRAM 9
1975 1977 1980 1982 1985 1987 1990 1992 1995 1997 2000 2002 2005 2007 2010 2012 2015 2017 2020 2022 2025
YEAR

DIAGRAM 10


E ENERGY DEMAND
O OIL DEMAND
2 OIL PRODUCTION IN DEVELOPING COUNTRIES
P OIL PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES
Million barrels per day
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.000
60.000
40.000
20.000
0.0
1975 1977 1980 1982 1985 1987 1990 1992 1995 1997 2000 2002 2005 2007 2010 2012 2015 2017 2020 2022 2025
YEAR


E ENERGY DEMAND
O OIL DEMAND
3 OIL PRODUCTION IN DEVELOPING COUNTRIES
P OIL PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES
Million barrels per day
140.00
130.00
120.00
110.00
100.00
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.0
DIAGRAM 11
2002 2005 2007 2010 2012 2015 2017 2022 2025
YEAR

CONCLUSIONS

The conclusion that emerges from the above description and arguments can be summarized as follows:

There seems to be a real shortage in the oil supply needed to meet demand arising from the Lima target. The maximum period for which the future oil demand can be sustained at the potential production rate is 16 years. This being so, oil reserves will be exhausted before we have progressed two-thirds of the way towards the Lima target. Undoubtedly, oil enjoys the preferred place in the category of energy resources. Currently, oil accounts for about 55 per cent of the total primary (commercial) energy requirements in the world, and would continue to be so until the year 2000, when its share will be 50 per cent of the total primary resources provided there are no constraints from the side of the oil supply. But, given the supply constraints of oil and under the Lima scenario, energy resources, other than oil, will have to meet about 75 per cent of the total energy requirements in the year 2000.

As to the alternative energy resources, coal and nuclear power are supposed to be the genuine options. But in the developing countries, coal is merely 5 per cent of the world's known reserves, and that too is rather unevenly distributed geographically. And the nuclear power is neither feasible nor is safely desirable as an option for the developing countries for the next few decades. In considering that if all the oil produced in developing countries (OPEC and non-OPEC) is being reserved for the use of these countries alone, oil supply would meet demand only until the year 2004 under the Lima scenario. But this option is certainly out of the question and it is neither politically practicable nor it is economically desirable.

Having, therefore, considered the various energy options in the light of the Lima target, it is suggested that:

(i) The developing countries should plan to economize on oil and other energy resources in order to accomplish their industrialization aspirations and economic development harmoniously. Of course, the situations are not the same in the OPEC and non-OPEC countries, and even within the OPEC countries, this depends very much on the need for various development projects in the respective countries. However, it might be highly desirable to avoid intensive energy-consuming technology. In other words, when constructing an over-all plan of the economy, due emphasis is to be placed on the energy sector and the use of energy in other sectors, particularly with respect to the appropriate choice of the technology spectrum and product mix.

(ii) The developed countries should conserve energy and avoid waste and also divert more concerted efforts towards technological developments so as to extend the current concept of measured resource availability. The emphasis, so to speak, should be focused on discovery, exploration, recovery, and t he use of technologies as related to the energy resources.

(iii) An appropriate plan for sharing the existing known supply of oil, so as to serve the interests of the international community is very much called for.

(iv) A joint effort should be made in order to promote Research and Development regarding energy resources and their foreseeable future use.

A TECHNICAL NOTE ON FUTURE ANNUAL OIL PRODUCTION RATE ESTIMATES

According to the report of the Workshop on Alternative Energy Strategies, four different factors determine the annual rate of world oil production. The first factor is the amount of crude oil which is ultimately recoverable: latest estimates indicate some 2000 billion barrels, the more pessimistic figure being 1600 billion barrels. The second, and more immediately relevant, factor is the estimate of proven oil reserves at the end of each year. For any specific year these consist of the total cumulative production up to that time plus the remaining proven reserves. Oil and Gas Journal (29 December 1975) estimates the end-1975 figures as: the cumulative production in the past, 341 billion barrels (291 billion barrels for non-communist countries) and the total remaining proven reserves, 658 billion barrels (555 billion barrels for non-Communist countries).

The third factor is an estimate of future annual rate of gross additions to reserves as a result of new discoveries and improved recovery techniques. Additions to reserves due to new discoveries averaged about 22 billion barrels per year between 1950 and 1965, over 50 billion barrels per year in the five years between 1965 and 1970, and around 25 billion barrels per year since 1970. The percentage of oil recoverable from the ground varies from field to field (10 per cent to 80 per cent). The current estimate is that the global average recovery rate is 30 per cent. This recovery rate will gradually improve and WAES assumes that 50 per cent of the new additions will come from enhan ed recovery by the end of the century. This being said, WAES adopts two future rates of gross additions to reserves: 20 billion barrels per year and 10 billion barrels per year. Our calculation abides by these WAES assumptions.[1/]

The fourth factor is a so-called "reserves-to-production" (R/P) ratio, which imposes a physical limit to the annual rate of oil production. Oil recovery relies on natural pressure within the reservoir and the maximum yield is obtained by releasing this pressure at a controlled rate. WAES estimates an R/P ratio of 10:1 to constitute a maximum and an R/P ratio of 15:1 to be a minimum technically desirable rate of annual oil production.

The level of the (remaining) proven oil reserves for each year is therefore determined by adding to the reserves proven at the end of one year the gross additions to the reserves during that year, whereafter actual production (consumption) during that year is subtracted. The maximum potential production is determined by multiplying the annually changing (remaining) proven reserves by the inverses of the limiting R/P ratios. For all our calculations, the end of 1975 proven reserves (658 billion barrels) is taken as the current year proven reserves for 1976.

1/ Although it may need an expert in oil to judge the reasonableness of these growth rate projections, it does seem that WAES has made an error. WAES rightly points out that the average annual rate of new additions to reserves in the past due to new discoveries can be computed using two different accounting systems. One system backdates and attributes new estimates of reserves to the year in which they were originally discovered; the other compares year-end proven reserves figures when they are revised due to new discoveries. Based on the actual estimates of additions to reserves between 1970 and 1975, WAES obtains, not surprisingly, two different results: 15 billion barrels per year rate by the backdating method and 25 billion barrels per year rate by the current year-end reserve estimate method. WAES asks Which of the two methods is best? and concludes that " ..... in looking at future discovery rates, we should look at results from both these methods". (WAES p.121)

If we refer this conclusion to the 20 billion barrels per year rate WAES has adopted, this figure definitely becomes suspect. Taking an average of two results based on two different accounting systems is akin to taking an average value of an object measured in inches and centimetres. Furthermore, there is absolutely no question which method is superior. The backdating method, whatever its merit in business accounting, is grossly unsuited to projecting future production rates. According to the established formula, the maximum oil production ceiling in any particular year is based on the actual estimates of the remaining proven reserves of that year. Obviously, if the backdating method were used, the size of proven reserves remaining in the current year cannot be determined as long as there is a chance that the figure will be "updated" in the future. This is precisely why WAES wants to determine the future gross additions rate in advance and to have such rates distributed over "the future".