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FUNDING ON ENERGY RESEARCH AND DEVELOPMENT IN SOUTH AFRICA

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I N D E X

SUMMARY

An analysis is made of the funding on energy research and development in South Africa and is compared with the funding of seventeen countries making up the International Energy Agency. The survey is incomplete because of the lack of adequate accounting methods in certain organisations supplying statistics which did not allow for a subdivision into energy and other funding. It is also incomplete because certain organisations were unwilling to give information because of fear of contravening the Petroleum Act.

An analysis of research funding by private industry, and especially by overseas controlled companies, has shown that very little is done in this country, most companies preferring to rely on research carried out by their parent companies overseas.

Sufficient information was obtained to show that with the exception of funding for nuclear power South Africa's research effort is below that of most countries of the I E A. This is especially true of funding on coal research where South Africa should, in terms of its position as a major coal exporting country, and because of its heavy reliance on domestic coal consumption, be one of the world's leaders in coal research. However, only Italy, of the 17

I E A countries, spends less on coal research in terms of funding per ton of coal mined. In the field of research into renewable energy forms South Africa is far behind any of the other countries considered.

It is suggested that in 1979 South Africa should have spent R 102 Million on energy research and development in place of the approximately R 45 Million actually spent.

It is recommended that an Energy Research and Development Fund should be set up, financed by a tax on the various forms of energy consumed or exported. Thus there should be a tax on each litre of liquid fuel sold, on each ton of coal consumed, on each ton of coal exported, and on each ton of Uranium exported. This central fund should be used to finance research of benefit to the country and in line with energy policy as it develops.

The suggested levels of government funding in the various sectors for 1979 are given in detail in Table 8 of the report and are summarised below.

	Actual	Recommended
Conservation	R 0,25 M	R 1,3 M
Oil & Gas	0,28	2,8
Coal	4,84	50,0
Nuclear	37,05	37,1

	Actual	Recommended
	R 42,42	R 91,2
Renewable	0,27	4,0
Other	2,43	6,8
	R 45,12	R 102,0

1 INTRODUCTION

Until the O P E C action in raising oil prices in 1973, most countries did not have an energy policy or a programme for energy research and development. The one possible exception to this was the nuclear energy programme of a number of countries, but this was seen as an economic and technology export commitment rather than part of an overall energy picture. The end of the cheap-oil era changed this picture but until now most of the efforts to produce an energy policy, to produce guide lines for the future, have been at the committee discussion level rather than at the implementation stage. A number of countries, notably the International Energy Agency (I E A) group have recognised the need for a rational approach towards an overall energy policy and have recognised that a Research and Development Programme is a vital component of any Energy Policy. Energy R & D must answer the questions put forward by planners, and be able to direct the planners to possible new areas of energy supply and demand.

Energy Research and Development must therefore be planned to aid in the Energy Policy Formulation mechanism and, in view of the long term nature of some of the research projects, action on R & D must be taken timeously and funding must be arranged in an on-going fashion; very little can come out of a start-stop or an ad-hoc research programme.

The difficulties facing any energy policy maker when trying to decide on R & D programmes is :

(a) which projects should be supported
(b) what priorities should be assigned to each project
(c) how much funding should be allocated

The question of total energy R & D funding can possibly be discussed by comparing South Africa's funding with that of other countries. Cognisance must be taken however of the difference in the energy mixes of other countries, and of South Africa's particular situation as regards its geographical, political and strategic considerations.

Once the question of how much funding should be allocated to Energy R & D in general has been agreed, it will be possible to allocate funds to the various energy sectors by analysing the priorities of each sector in the South African context.

When allocating priorities it should be remembered that research over a wide front is necessary even though some of it may be at a shallow level since it is only by working in a field that one is able to understand the developments overseas and to see possibilities which might occur due to South Africa's unique requirements.

2 FUNDING SURVEY

In order to determine how South Africa compares, in terms of Energy Research and Development Funding, with other countries in the world a survey was made of spending on Energy R & D during the years 1979 and 1980. All the government and statutory bodies which are known to carry out research in the field of energy were approached and were asked to fill in a questionnaire such as that in Appendix A.

In many cases it was difficult to obtain this information because expenditure figures were not available in the form required. In certain cases the information was unobtainable because the organisations concerned claimed this would be a contravention of the Petroleum Act. In general comprehensive information was obtained from the C S I R, the Fuel Research Institute (F R I) and from E S C O M. The return from the Atomic Energy Board (A E B) included both funding on energy research and on its other activities such as isotope applications, since separate accounts are not kept of the various areas. Thus the A E B funding is heavily inflated. However, the A E B funding does not include the amounts spent on the Uranium Enrichment programme and thus the overall figure quoted is likely to be an underestimate.

No returns were obtained from a number of other government departments for a variety of reasons.

Sasol did not submit a reply since they considered that the funding in this category was for improvements to their existing operation and did not come under the heading of R & D but rather under Operations.

A submission was received from S O E K O R but the funding indicated was for oil exploration rather than for the generally accepted definitions of Energy R & D. Their funding has been included in the list of organisational funding in Table 1 of this report but has not been used for comparison with other countries.

The submission from the National Institute of Metallurgy (N I M) was in the form of an estimate of the percentage of total expenditure assumed to be for energy purposes since the N I M do not have an accounting subdivision for energy. They assumed that 5 % of their budget relates directly to energy matters and mainly in the area of energy conservation.

A number of private firms were approached for details of their R & D funding but most replied that their energy R & D work was carried out by their parent company overseas and they did not do any work in this country. One of the notable findings of this survey was the very small concern paid by private industry to the energy scene in South Africa.

Because of the above limitations the results of this survey cannot be considered an accurate picture of the energy R & D scene in this country. It is the hope that a follow up survey can be carried out later and more responses obtained. However the main stumbling block to an accurate assessment of energy R & D in South Africa is the Petroleum Act. However, in spite of this inaccuracy the relative comparison with spending of other countries is valid and will give a lead to the required level of research spending in South Africa.

3 SURVEY ANALYSIS

The funding of the various organisations is given in Table 1 in terms of the government sector spending, private sector spending, and oil exploration. In the analysis that follows, the oil exploration amount has been omitted, for the reasons already stated. The private sector spending has also been omitted because it is small (less than 3 % of government spending) and because the results available for other countries refer to government spending only.

From Table 1 it will be seen that 82,1 % of government and statutory body spending is for nuclear power and 10,7 % is for coal. The results of Table 1 are shown diagrammatically in Figure 1.

The analysis of institutional spending is given in Table 2 where it can be seen that the largest spender on R & D is the Atomic Energy Board followed by E S C O M, and with the C S I R and the F R I behind them. In this analysis the C S I R & F R I are given separately since at that time (1979/1980) the F R I had not been incorporated into the C S I R.

4 INTERNATIONAL COMPARISON

The amounts spent on the various areas of Energy R & D in South Africa, as given in Table 1, can now be compared with other countries, and especially with the countries of the I E A since that organisation publishes yearly analyses of R & D spending of its member countries. The figures for the I E A countries have been abstracted from various reports and a cost comparison for 17 countries for 1979 is given in Table 3. The countries used for the comparison are :- Austria, Belgium, Canada, Denmark, West Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, U K, and U S A. Table 3 summarises the Government Energy R & D funding for the various sectors, in U S dollars in 1979.

The countries compared in Table 3 vary in population, G D P, energy consumption etc and these differences are highlighted in Table 4 and in Figure 2. Most of the countries show a good correlation between per capita energy consumption and G D P. Notable exceptions are Denmark and Switzerland, which have an energy consumption of approximately half of the average, and Canada, U S A and South Africa which have much higher than average energy consumption. The very high and very low energy consumptions reflect the different industrial mixes in the countries concerned with Denmark for instance having mainly agricultural and secondary industry whilst South Africa has a very high mining component.

Table 5 shows the percentage of total government energy R & D budget devoted to Nuclear Power. This is shown diagrammatically in Figure 3. South Africa spends 82 % of its total energy research funding on nuclear power which is well up with the leaders, Italy (86 %) and Japan (84 %). Both Italy and Japan are heavily dependant on imported energy (80 % and 90 % respectively) and it makes sense for them to spend a large proportion of their budget on nuclear power. One third of Japan's nuclear research spending is on Fusion and Fast Breeders whilst 45 % of Italy's research spending is in this category. By comparison South Africa's budget for nuclear research appears excessive in terms of our potential reliance on nuclear power. However, in terms of spending per unit of primary energy (last column in Table 5) South Africa's spending is modest - equivalent to that of Denmark and Spain, and approximately one third of that of Japan. It therefore appears that the total amount spent on nuclear research is not excessive but in comparison with the very low funding for general energy R & D the percentage appears excessive.

Table 6 shows the government funding for research on coal. Two methods of correlation are given in Table 6, in terms of funding per ton on coal consumed, and in terms of funding per unit of primary energy. In view of the differences between the energy mixes of the various countries the second of these correlations does not give a true picture of the spending pattern and it is the first correlation - funding per ton of coal consumed that has been used in Figure 4. It is obvious that South Africa with its great reliance on coal has completely inadequate funding for coal research. It is in fact second lowest in funding, only Italy having a lower funding. The present funding, including C S I R funding and the funding derived from the levy on coal for the F R I, amounts to 8 U S Cents per ton compared with a weighted average of the countries enumerated of 83 U S Cents per ton. South Africa, with its high reliance on coal in its internal energy consumption, its high export potential, and its future reliance on coal for liquid fuels, should be spending at least as much on coal R & D as the large coal usersand it is suggested that the funding, in 1979, should have been on a par with the weighted average. Thus in 1979 South Africa should have spent approximately 83 U S Cents per ton.

Table 7 shows the comparative spending on the various forms of renewable energy. The totals of Table 7 are shown diagrammatically in Figure 5 where it is seen that South Africa's funding in this area is way below that of any other country in the list. South Africa spends approximately 2 % of that of Sweden, and approximately 6 % of the average of the countries listed. Whilst South Africa, with its cheap coal, does not need to resort to renewable energy as soon as some other countries,nevertheless it is considered that the present funding is inadequate since it is not sufficient for enough work to be carried out in order to be able to understand and keep up to date with overseas developments. South Africa should at least be on a par with a country such as Spain or Austria in terms of research on solar energy, it should be spending something like half of Britain's expenditure on wind energy and should be on a par with New Zealand or Ireland on Biomass research. Whilst scope for Ocean energy in South Africa is lower than in certain other countries, enough research should be carried out to be able to demonstrate the viability or otherwise of ocean energy. Funding should possibly be at a level of one-tenth of that of the U K.

In comparison with the funding of other countries on the remaining categories of Table 3, it is considered that South Africa should be spending five times as much as it is doing on conservation, twice as much on electric power, three times as much on energy storage, and twenty times as much on new energy forms. If the oil and gas sector includes research into engines for improving fuel consumption, using wider cut fuels etc then the spending should be increased by a factor of about 10.

5 FUNDING SUMMARY

With the exception of funding for nuclear research, South Africa is spending far less than other countries on energy research and development. By comparison with I E A countries South Africa spends less on renewable energy research (on a per energy unit basis) than any other country, and only Italy spends less on coal research (on a per ton basis) than does South Africa.

If funding on energy research was to be increased as suggested in the previous section, then South Africa would have spent, in 1979, an amount of R 102 M which, on a basis of per unit of energy, would have amounted to 0,041 U S $ per G J. This should be compared with the following typical values :

South Africa	(actual)	0,018 U S $/G J
	(recommended)	0,041
Austria		0,031
Belgium		0,051
Canada		0,016
W Germany		0,093
Japan		0,062
Netherlands		0,042
U S A		0,049

The complete list of "per energy unit" spending by countries of the I E A is given in Table 4.

The actual and recommended 1979 levels are given in Table 8. These are levels for 1979 and would have grown since then because of the increase in energy consumption and possibly because of an increased importance placed on energy. As South Africa increases its role as an energy exporter so the importance of energy R & D will increase.

6 FUNDING METHODS

Funding for energy R & D can be obtained either as a budget from Treasury or it can be obtained on the basis of a tax on energy. The energy tax is already in existence as a levy on transport fuel to finance the governments oil-from-coal programme. The same method is applied in New Zealand where a tax of 0,1 N Z Cents per litre on all transport fuel is levied to fund research into alternative transport fuels. This fund is administered by the Statutory body - the Liquid Fuels Trust Board (L F T B)- and in 1980 brought in over 3 M N Z dollars for research. In addition to this direct tax the New Zealand government also allocates additional funding to cover the research areas not covered by the L F T B.

Similarly in Australia a tax of 1 AUST $ is put on each ton of export coal. In non-energy fields similar funding methods are adopted, for instance in Malaysia a tax of 2 cents per kilogram of rubber exported is used to finance the Malaysia Rubber Producers Research Association. In South Africa the Water Research Commission administers research funding obtained from a levy on water used by industry.

It is therefore recommended that a central fund for energy research and development be instigated with funds obtained from a levy on energy consumption or export. Thus there should be a levy on liquid fuel used, on coal consumption, on coal exported, and on uranium exported. This fund should be administered in such a way as to benefit the energy policy of the country.

7 RESEARCH GOALS AND PRIORITIES

Energy research and development should be guided to provide answers to the questions required for energy policy making. Energy R & D can be divided into three sectors : short term, medium term, and long term. Long term research is concerned with determining the energy forms which might be available at the end of the century or thereafter. Such candidates as fusion reaction, hydrogen, etc come into this category. It is important to have some research going on in these areas since it is only by interacting on the international scene that South Africa can be aware of what research is being done which might have an impact on the South African scene. Reading articles and attending conferences is not enough - without actually participating in research such gestures are meaningless. However, much of this research is expensive, in certain cases such as fusion it requires international cooperation. Therefore the funding which can be devoted to such long-term research must be limited.

In the short term, up to five years say, there is generally little that can be done to influence the energy scene. Questions that must be answered in this period are usually fairly well defined and the funding required can be readily easily estimated. However, in South Africa, the situation is different since decisions must be made on the subject of petroleum replacement within this time period, decisions which could well affect the energy scene in the medium term.

Most of the funding is required for research on medium term problems. Relatively low funding is required on a broad base, those projects which appear to be important being gradually given more funding as results become available.

In order to be able to appreciate the time scale of the various energy fields an extract from Reference 4 is given in Table 9 whilst a more detailed analysis of the time scale for commercial realisation is given in Appendix B.

No attempt will be made here to recommend research priorities in the various fields, though the proposed funding levels discussed above do have a relation to priorities.

An analysis is currently being made of the relationship between policy and the energy research required to complement such policy.

8 REFERENCES

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4. A Group Strategy for Energy Research Development and Demonstration
International Energy Agency. O E C D Paris 1980

5. Report of the Liquid Fuels Trust Board of New Zealand - 31 March 1981
Government Printer, New Zealand 1981.

6. South African Year Book 1980/1981

9 ACKNOWLEDGEMENTS

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- Council for Scientific and Industrial Research
- Electricity Supply Commission
- Forestry Council Energy Committee
- Fuel Research Institute
- Mobil Oil Southern Africa (Pty) Ltd
- National Institute of Metallurgy
- Shell South Africa (Pty) Ltd
- S O E K O R
- Sugar Association
- Trek-Petroleum (Pty) Ltd

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10 NOMENCLATURE AND UNITS

T O E	-	Tons Oil Equivalent
T P E	-	Total Primary Energy
G J	-	10^9 Joules
G D P	-	Gross Domestic Product

1979 Conversion rate used R 1 = U S $ 1,1863

APPENDIX A - Copy of Survey Questionnaire

ENERGY RESEARCH & DEVELOPMENT FUNDING

Group	Nature	Funding R 1979	Funding R 1980
1	Conservation	....	....
2	Oil and gas	....	....
3	Coal	....	....
4	Nuclear	....	....
5	New Energy Sources -		
	Solar	....	....
	Heating/Cooling	....	....
	Photo Electric	....	....
	Thermal Electric	....	....
	Wind	....	....
	Ocean	....	....
	Biomass	....	....
6	Support Technologies -		
	Electric Power Conversion	....	....
	Electric Transmission/Distribution	....	....
	Energy Storage	....	....
	Energy System analysis	....	....
	Others	....	....
7	Other Sources	....	....
	TOTAL		

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A P P E N D I X   B

TABLES

TABLE 1 R & D Spending - Summary

		R 1 000's		%	
		1979	1980	1979	1980
Government Spending					
Conservation	CSIR	165,5	294,9		
	ESCOM	80,0	100,0	0,8	2,0
	NIM	-	500,0		
Oil & Gas	CSIR	224,2	289,7	0,6	0,8
	ESCOM	60,0	80,0		
Coal	CSIR	849,1	1 118,0		
	FRI	1 992,5	2 309,9	10,7	13,3
	ESCOM	2 000,0	2 500,0		
Nuclear	ESCOM	50,0	70,0	82,1	76,5
	AEB	37 000,0	34 000,0		
Solar	CSIR	232,3	216,8	0,5	0,5
Wind	CSIR	21,3	30,0	0	0,1
Ocean	CSIR	10,0	22,6	0	0,1
Biomass	CSIR	11,3	0	0	0
Electric Power	ESCOM	2 000,0	2 500,0	4,4	5,6
Energy Storage	CSIR	227,3	266,6	0,5	0,6
Battery Vehicles	CSIR	176,5	231,7	0,4	0,5
Hydrogen	CSIR	20,7	9,7	0	0
		45 120,7	44 539,9	100,0	100,0
Private Spending					
Coal	Ch of Mines	767,6	937,6		
Biomass	Forestry Council	150,0	60,0		
	SA Sugar Assoc	-	36,1		
Solar	Trek	1,0	1,0		
General	Shell		3,0		
		918,6	1 037,7		

TABLE 1 Continued

		R 1000's		%	
		1979	1980	1979	1980
Oil Exploration					
Oil + Gas	Soekor	49 973,0	62 966,0		
Total		96 012,3	108 543,6		

TABLE 2 Energy Funding - Totals R 1 000's

	1979	1980
SOEKOR	49 973,0	62 966,0
AEB	37 000,0	34 000,0
ESCOM	4 190,0	5 250,0
CSIR	1 938,2	2 480,0
FRI	1 992,5	2 309,9
NIM		500,0
CH OF MINES	767,6	937,6
FORESTRY COUNCIL	150,0	60,0
S A SUGAR ASSOC	-	36,1
SHELL	-	3,0
TREK	1,0	1,0
TOTAL	96 012,3	108 543,6

TABLE 3 1979 Government Spending on Energy R & D ($ Million)

	South Africa	Austria	Belgium	Canada	Denmark	West Germany
Conservation	0,3	7,1	7,8	10,7	2,9	45,1
Oil & Gas	0,3	0,6	0,6	5,7	-	10,4
Coal	5,7	2,3	6,4	8,4	1,0	166,0
Nuclear	43,9	6,1	72,8	91,0	13,1	677,6
Solar	0,3	2,2	3,5	9,1	0,9	29,6
Wind	0,03	0,6	-	1,9	1,8	7,6
Ocean	0,01	-	-	0,9	-	1,6
Biomass	0,01	3,3	0,7	5,6	0,8	1,6
Electric Power	2,4	2,0	1,7	2,7	0,2	82,7
Energy Storage	0,3	0,6	0,6	1,0	1,0	9,6
New Form	0,02	1,8	2,0	1,7	7,0	16,4
Other	0,2*	5,3	1,6	0,7	2,5	
	53,5	31,9	97,9	139,4	31,2	1048,2

* Battery Vehicles

TABLE 3 Continued

	Greece	Ireland	Italy	Japan	Netherlands	New Zealand
Conservation	0,1	1,2	10,7	51,3	14,5	4,2
Oil & Gas	-	-	-	21,2	3,5	0,6
Coal	1,6	0,8	0,6	19,4	5,3	0,8
Nuclear	1,3	0,6	185,3	774,3	62,1	0,02
Solar	0,54	0,3	11,6	16,9	5,7	0,2
Wind	0,1	0,1	0,1	0,3	3,9	0,1
Ocean	-	0,1	-	2,3	-	-
Biomass	0,1	0,9	-	0,3	0,3	0,5
Electric Power	0,05	0,7	0,3	7,0	3,8	0,11
Energy Storage	0,01	-	1,2	0,3	0,7	-
New Forms	0,3	-	1,8	22,2	0,2	1,5
Other	0,03	0,2	1,7	3,8	11,8	0,4
	4,13	4,9	213,3	919,3	111,8	8,43

TABLE 3 Continued

	Norway	Spain	Sweden	Switzerland	U K	U S A
Conservation	6,9	3,1	34,2	4,8	34,7	211,7
Oil & Gas	15,9	0,3	-	0,1	40,2	142,5
Coal	0,1	8,1	2,7	1,5	19,7	520,1
Nuclear	3,9	53,3	19,1	32,2	250,8	1 628,2
Solar	0,4	7,3	16,9	6,2	2,0	363,5
Wind	0,7	0,2	8,4	0,04	1,1	53,8
Ocean	3,4	-	0,8	-	9,5	42,2
Biomass	0,4	1,0	5,6	2,0	1,6	27,7
Electric Power	3,9	-	1,4	1,2	0,1	204,6
Energy Storage	0,1	-	0,5	0,5	0,1	50,3
New Forms	2,7	2,9	2,2	1,5	4,92	160,4
Other	1,3	3,1	15,0	2,6	291,2	378,4
	39,7	79,3	106,8	52,64	700,2	3 783,4

TABLE 4 1979 Energy R & D Statistics (U S $'s)

	Government R & D	Private R & D	Total R & D	G D P/ Capita 1000 US $	G J/Capita	Government R & D/Capita US $	Government R & D/G J	Government R & D/G D P
South Africa	53,5	1,1	54,6	1,5	102	1,8	0,018	1,20
Austria	31,9			9,2	139	4,2	0,031	0,46
Belgium	97,7			11,3	196	9,9	0,051	0,88
Canada	139,4			9,4	359	5,9	0,016	0,62
Denmark	31,2			12,8	157	6,1	0,039	0,47
W Germany	1048,2	329,0	1377,2	12,3	185	17,1	0,093	1,39
Greece	4,1			4,0	65	0,4	0,007	0,11
Ireland	4,9			4,6	106	1,5	0,014	0,32
Italy	213,3	124,4	337,7	5,6	103	3,7	0,037	0,67
Japan	919,3	512,7	1432,0	8,8	129	7,9	0,062	0,90
Netherlands	111,8	108,6	220,4	10,8	192	8,0	0,042	0,74
New Zealand	8,4	2,4	10,8	6,7	139	2,7	0,019	0,40
Norway	39,7	46,1	85,8	11,1	219	9,7	0,045	0,87
Spain	79,3	16,9	96,2	5,3	78	2,1	0,027	0,40
Sweden	106,8			12,5	257	12,9	0,050	1,05
Switzerland	52,6	192,4	245,0	14,9	158	8,3	0,053	0,56
U K	700,2	267,0	967,2	7,0	159	12,6	0,079	1,78
U S A	3783,4	1309,1	5092,5	10,7	350	17,2	0,049	1,61

TABLE 5 Government R & D Funding for Nuclear Power in 1979

	Government Nuclear R & D funding, 1979	
	As %age of total energy R & D	U S $ per GJ of primary energy
S A	82 %	0,015
Austria	19	0,006
Belgium	75	0,038
Canada	65	0,011
Denmark	42	0,016
W Germany	65	0,060
Greece	31	0,002
Ireland	12	0,002
Italy	86	0,032
Japan	84	0,052
Netherlands	56	0,023
New Zealand	-	0,000
Norway	10	0,004
Spain	67	0,018
Sweden	18	0,009
Switzerland	60	0,032
U K	-	-
U S A	43	0,021

TABLE 6 Government R & D funding for coal in 1979

	Coal Consumption M ton/year	Coal R & D U S $/ton	Coal R & D per T P E* U S Cents/G J
S A	74,9	0,08	0,408
Austria	2,8	0,82	0,221
Belgium	15,5	0,41	0,332
Canada	31,6	0,27	0,100
Denmark	6,6	0,15	0,124
W Germany	78,1	2,13	1,467
Greece	0,5	3,20	0,262
Ireland	1,0	0,80	0,233
Italy	13,6	0,04	0,010
Japan	76,2	0,25	0,130
Netherlands	4,6	1,15	0,197
New Zealand	1,8	0,44	0,182
Norway	0,7	0,14	0,011
Spain	15,5	0,52	0,276
Sweden	1,9	1,42	0,126
Switzerland	0,1	15,00	0,151
U K	-	-	-
U S A	607,5	0,86	0,674

* T P E - Total Primary Energy - G J

TABLE 7 Government R & D funding for renewable energy in 1979 (U S Cents)

	R & D funding/G J of primary energy				
	Solar	Wind	Ocean	Biomass	Total
S A	0,021	0,002	0,001	0,001	0,025
Austria	0,211	0,058	0	0,316	0,585
Belgium	0,181	0	0	0,036	0,217
Canada	0,107	0,022	0,011	0,066	0,205
Denmark	0,111	0,222	0	0,099	0,433
W Germany	0,261	0,067	0,014	0,014	0,357
Greece	0,088	0,016	0	0,016	0,121
Ireland	0,087	0,029	0,029	0,262	0,407
Italy	0,198	0,002	0	0	0,200
Japan	0,113	0,002	0,015	0,002	0,132
Netherlands	0,212	0,145	0	0,011	0,368
New Zealand	0,045	0,023	0	0,114	0,182
Norway	0,045	0,078	0,381	0,045	0,549
Spain	0,248	0,007	0	0,034	0,289
Sweden	0,791	0,393	0,037	0,262	1,483
Switzerland	0,622	0,004	0	0,200	0,826
U K	0,022	0,012	0,107	0,018	0,160
U S A	0,471	0,070	0,055	0,036	0,631

TABLE 8 Actual Funding for Energy Research and Development in 1979 together with levels which it is considered should have been allocated in 1979.

	R & D Funding (R Millions)	
	Actual	Recommended
Conservation	0,25	1,3
Oil & Gas	0,28	2,8
Coal	4,84	50,0
Nuclear	37,05	37,1
Solar	0,23	2,7
Wind	0,02	0,1
Ocean	0,01	0,1
Biomass	0,01	1,1
Electric Power	2,00	4,0
Storage (incl battery)	0,41	1,2
New energy forms	0,02	0,4
Misc (e g analysis)	0	1,2
	45,12	102,0

TABLE 9 Dates of commercial realisation of various processes (Reference 4)

	Unit Size	Start Year
Alternative Transport Fuels		
- Methanol from gas	3 M toe/year	1985
- Methanol to gasoline	1 M toe/year	1985
- Gasoline from gas	2 M toe/year	1985
Ocean Power		
- Wave central plant	2 MWe	1990
- Ocean temperature difference	100 MWe	2000
- Tidal	800 MWe	1985
Solar Electric		
- Solar photovoltaic	10 kWe	1985
- Central thermal	150 MWe	2000
- Central photovoltaic	1 MWe	1990
Wind Power		
- Central wind power	2 MWe	1985
- Local wind power	20 kWe	1985
Nuclear		
- Breeder	1 000 MWe	1995
- Process heat	2 M toe/year	2000
- Fusion	750 MWe	2020
Magnetohydrodynamics		
- Coal M H D	1 932 MWe	2005
Hydrogen Production		
- Hydrolysis of water	0,002 M toe/year	1985
- Thermal decomposition	1 M toe/year	2000

Table from Reference 4 -

A GROUP STRATEGY FOR ENERGY RESEARCH DEVELOPMENT AND DEMONSTRATION, I E A 1980

TABLE II-1 : **CONDENSED REFERENCE TECHNOLOGY DATA**

TECHNOLOGY	UNIT SIZE	REFERENCE START YEAR*	EFFICIENCY %	NOTES (see p. 73)
END-USE				
AUTOMOTIVE TRANSPORT SYSTEMS:				
Nuclear Powered Ship, PWR (Marine) (See also Table II-2)	1 Mtoe/yr	2000	–	Jap
ALTERNATIVE TRANSPORTATION FUELS: (See: Coal Liquefaction; Fuels from Biomass; Non-fossil Hydrogen Systems. Also see Table II-2)				
Production of Methanol from Natural Gas	3 Mtoe/yr	1985	60	NZ
Conversion of Methanol to Gasoline (MOBIL)	1 Mtoe/yr	1985	86	NZ
Production of Gasoline from Natural Gas (SYNTHOL)	2 Mtoe/yr	1985	43	NZ
CONSERVATION BUILDING - EQUIPMENT:				
Seasonal Low-Temperature Heat Storage, Underground (See also Table II-2)	8 Mtoe/yr	1990	70	Ita
ELECTRIC AUTO: (See Table II-2)				
INDUSTRIAL CONSERVATION:				
Binary Cycle Cogeneration, Medium Temperature Heat	1 MWe	1990	5	Ita, 7
Industrial Cogeneration, Gas Turbine	80 MWe	1985	30	US, 7
Industrial Cogeneration, Coal-Steam Back Pres.Turbine	30 MWe	1985	13	7
Industrial Cogeneration, Diesel	–	1985	35	7
Medium Temperature Heat from Solar (See also Table II-2)	1 Mtoe/yr	1980	–	Ita
RESIDENTIAL AND COMMERCIAL SOLAR: (See Table II-2)				
PRODUCTION				
ENHANCED GAS RECOVERY: (Treated as domestic extraction via supply curve)		1985		3
ENHANCED OIL RECOVERY: (Treated as domestic extraction via supply curve)		1980		2
GEOPRESSURIZED METHANE: (Treated as domestic extraction via supply curve)		1990		US
GEOTHERMAL/HYDROTHERMAL:				
Geothermal/Hydrothermal Power Plant (existing technology in several countries, historical data used for each country)				
HOT DRY ROCK:				
Dry Geothermal (Hot Rock) Power Plant	100 MWe	1990	–	
District Heating Plant, Geothermal		1980	–	Jap

TABLE II-1 : **CONDENSED REFERENCE TECHNOLOGY DATA (CONTINUED)**

TECHNOLOGY	UNIT SIZE	REFERENCE START YEAR*	EFFICIENCY %	NOTES (see p. 73)
OCEAN POWER:				
Wave Central Electric Power Plant	2 MWe	1990	–	
Ocean Thermal Gradient Electric Power Plant	100 MWe	2000	–	
Tidal Electric Plant	800 MWe	1985	–	
SHALE OIL AND TAR SANDS:				
Tar Sands Processing, Flexicoking	9 Mtoe/yr	1980	82	Can
SOLAR ELECTRIC:				
Decentralized Solar Photovoltaic	10 kWe	1985	–	
Central Solar Thermal Electric	150 MWe	2000		
Central Solar Photo-Voltaic Power Plant	1 MWe	1990		
WIND POWER:				
Wind Turbines, Central Electric Power Complex	2 MWe	1985	–	
Local, Wind Electric Generator	0.02 MWe	1985	–	
CONVERSION				
ADVANCED CONVERTER REACTORS:			(Note 6)	
ATR Nuclear Power Plant	1000 MWe	1980		Jap
CANDU Nuclear Power Plant, Enriched Fuel	1000 MWe	1990		Can
CANDU Nuclear Power Plant, Highly Enriched Fuel	1000 MWe	2000		Can
AGR Nuclear Power Plant	1000 MWe	1980		UK
HTR Nuclear Power Plant	1000 MWe	1995		
Nuclear Process Heat, VHTR, Enriched Uranium Fuel	2 Mtoe/yr	2000		Jap
Nuclear Process Heat, VHTR, U33 Fuel	2 Mtoe/yr	2010		Jap
Nuclear Process Heat, CANDU-ORC	2 Mtoe/yr	1990		Can
VHTR Nuclear-Coal, Reducing Gas		2000		Jap
(See Technology under High Caloric Gasification for nuclear systems used for coal gasification				
BREEDER REACTORS:				
LMFBR Nuclear Power Plant	1000 MWe	1995	(Note 6)	
COAL LIQUEFACTION:				
Hard Coal Liquefaction, Hydrogenation	9 Mtoe/yr	1995	65	1985 US
Hard Coal Liquefaction, Fischer-Tropsch	8 Mtoe/yr	1995	58	1,1985 US
Hard Coal Liquefaction, SRC-2 Process	2 Mtoe/yr	1995	70.3	Jap.
Methanol Production from Hard Coal	2 Mtoe/yr	1990	46	1,1985 US
Brown Coal Liquefaction, Hydrogenation	2 Mtoe/yr	1995	55	
Brown Coal, Methanol Production by LURGI		1995	46	1,1980 Can
COMBINED CYCLE, LOW QUALITY GASIFICATION: (including Fluidized Bed Combustion)				
Hard Coal Combined Cycle Power Plant	1200 MWe	1990	44.9	1
Pressurized Fluidized Bed Power Plant	1000 MWe	1995	43	
Atmospheric Fluidized Bed Power Plant	1000 MWe	1990	38	
Atmospheric Fluidized Bed Industrial Boiler for Process Steam	28 MWth	1985	70	US
FUEL CELL (COAL DERIVED FUEL):				
Gas Fuel Cell	26 MWe	1985	40	
FUELS FROM BIOMASS:				
Coal/Municipal Waste, Steam Electric	350 MWe	1980	32.2	4, US
Coal/Municipal Waste, Steam Electric	350 MWe	1980	32.2	US
Biomass Steam Electric Power Plant	50 MWe	1985	31	1980 Can, Nor, Swe
Methanol from Wood	1 Mtoe/yr	1985	40	
Gas from Wastes		1985		Ita

TABLE II-1 : CONDENSED REFERENCE TECHNOLOGY DATA (CONTINUED)

TECHNOLOGY	UNIT SIZE	REFERENCE START YEAR*	EFFICIENCY %	NOTES (see below)
FUSION:				
Nuclear Fusion Power Plant	750 MWe	2020	(Note 6)	2010 Can
HIGH CALORIC GASIFICATION OF COAL:				
Hard Coal, Nuclear Hydrogasification	5 Mtoe/yr	1995	43.1	
Hard Coal Gasification, Nuclear Combined Hydro/Steam	3 Mtoe/yr	1995	69.5	
Hard Coal, High Btu Gasification, LURGI-Slagging	5 Mtoe/yr	1990	60	
Brown Coal, Nuclear Hydrogasification	4 Mtoe/yr	1995	48.4	
Brown Coal, Nuclear Steam Gasification	4 Mtoe/yr	1995	56.8	
Brown Coal, High Btu Gasification, LURGI-Slagging	4 Mtoe/yr	1990	65	1,1985 Can
LOW TO MEDIUM CALORIC GASIFICATION OF COAL:				
Hard Coal, Medium Btu Gasification	1 Mtoe/yr	1990	60	1
Hydrogen Production from Hard Coal	2 Mtoe/yr	1980	66	Can
Brown Coal, Medium Gasification, Winkler Process	2 Mtoe/yr	1980	60	
Prod. of Reducing Gas from Coal & Nuclear Process Heat		2000	52.3	
MAGNETOHYDRODYNAMICS:				
Coal MHD Electric Power Plant	1932 MWe	2005	48	
NON-FOSSIL HYDROGEN SYSTEMS:				
Hydrogen Production by Electrolysis of H_2O	.002 Mtoe/yr	1985	76	1980 Can. Nor
Hydrogen Production by Thermochemical Splitting using Nuclear Process Heat	1 Mtoe/yr	2000	38	5
UNDERGROUND COAL GASIFICATION				
Underground Gasification with Combined Cycle Electric Power Plant	170 MWe	1990	22.7	
In Situ Coal Gasification	2 Mtoe/yr	1985	58	

* REFERENCE START YEAR is defined as the year in which the reference technology could begin commercial operation (date available plus lead time for design and construction). In some cases, for special reasons, the technology could start operation in one country at an earlier date. Such exceptions are listed in the Note column.

NOTES FOR TABLE II-1

Technologies used in only one country are noted by country abbreviations:

Aus	Austria	Jap	Japan
Bel	Belgium	NZ	New Zealand
Can	Canada	Nor	Norway
Den	Denmark	Spa	Spain
Ger	Germany	Swe	Sweden
Ire	Ireland	UK	United Kingdom
Ita	Italy	US	United States

1. Efficiency improves in later years.
2. "Enhanced Oil Recovery" is defined as tertiary oil recovery using steam, CO_2 miscible, micellar polymer and in-situ combustion processes. Secondary recovery using water flooding is included under conventional oil recovery. Enhanced Oil Recovery was divided into three production cost groups: $7.50/bbl, $12.50/bbl, and $20.00/bbl, each with a defined total resource.
3. "Enhanced Gas Recovery" is from Devonian Shales, Coal Seams, and Western Tight Sands. The resources have been divided into two production cost classifications: $2.00/Mcf and $6.00/Mcf.
4. Includes sulphur abatement equipment.
5. Unit size and costs refer to hydrogen output.
6. The MARKAL model does not make direct use of the thermal efficiency of the nuclear system. Instead the input datum lists the tonnes of fuel required to produce one petajoule of net electric energy putput. This value is embodied in the fuel cycle parameters which cannot be summarized in simple form.

A P P E N D I X C

FIGURES

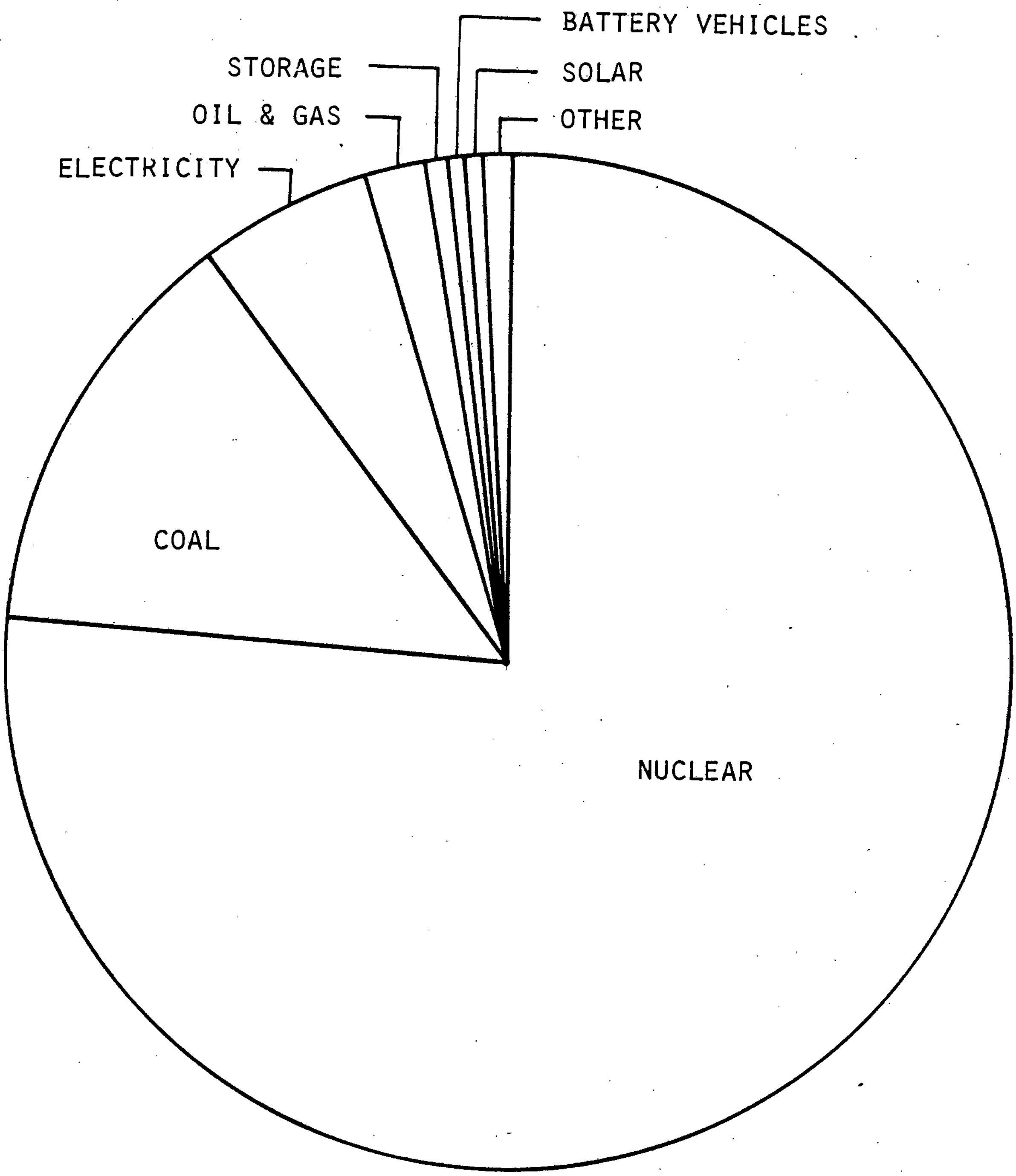
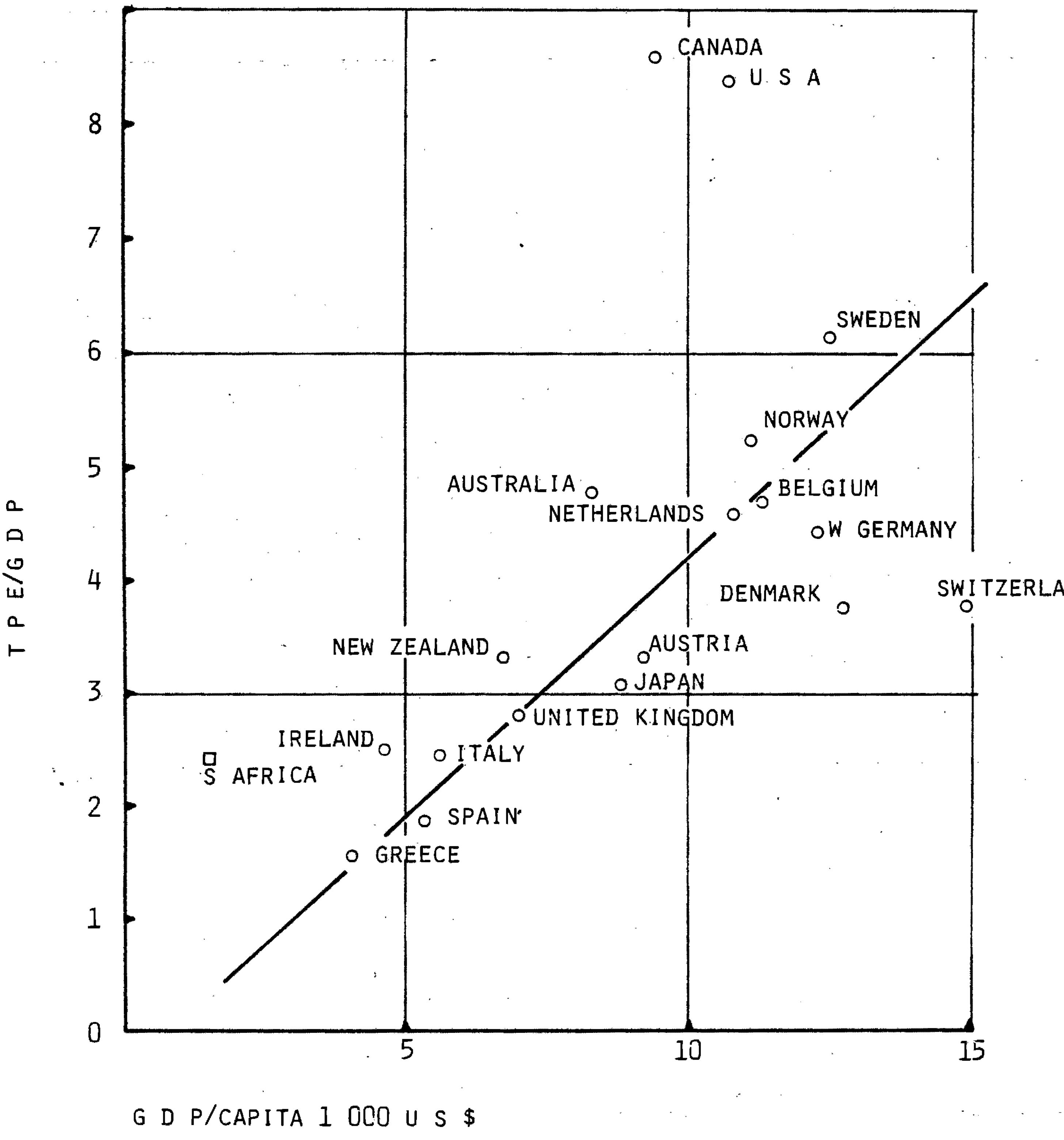


FIGURE 1 : DISTRIBUTION OF S A GOVERNMENT RESEARCH & DEVELOPMENT FUNDING FOR ENERGY IN 1979

FIGURE 2 : RELATIONSHIP BETWEEN PER CAPITA GROSS DOMESTIC PRODUCT (G D P) AND TOTAL PRIMARY ENERGY (T P E) CONSUMPTION



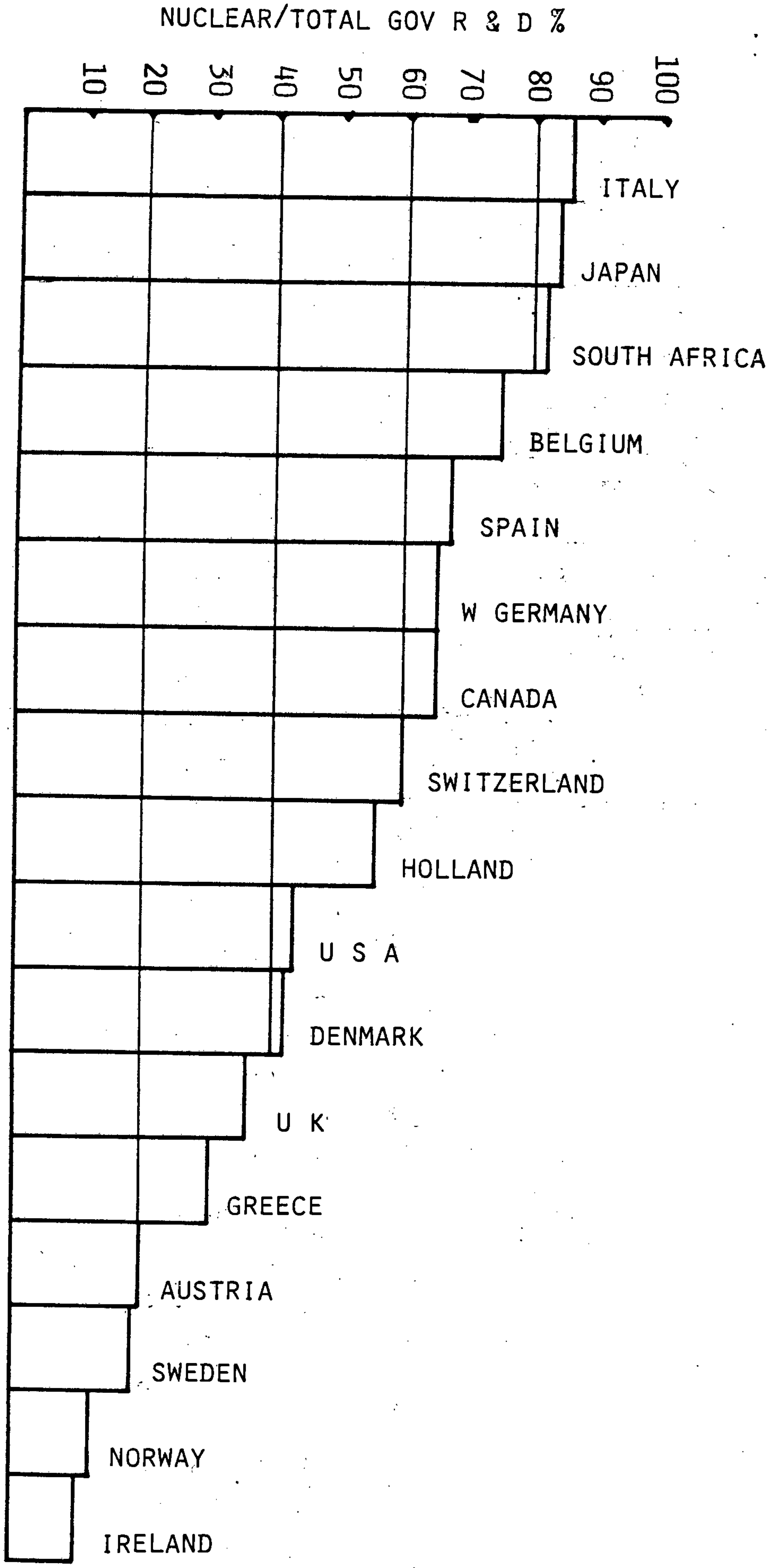


FIGURE 3 : GOVERNMENT NUCLEAR R & D FUNDING AS A PERCENTAGE OF GROSS ENERGY R & D FUNDING

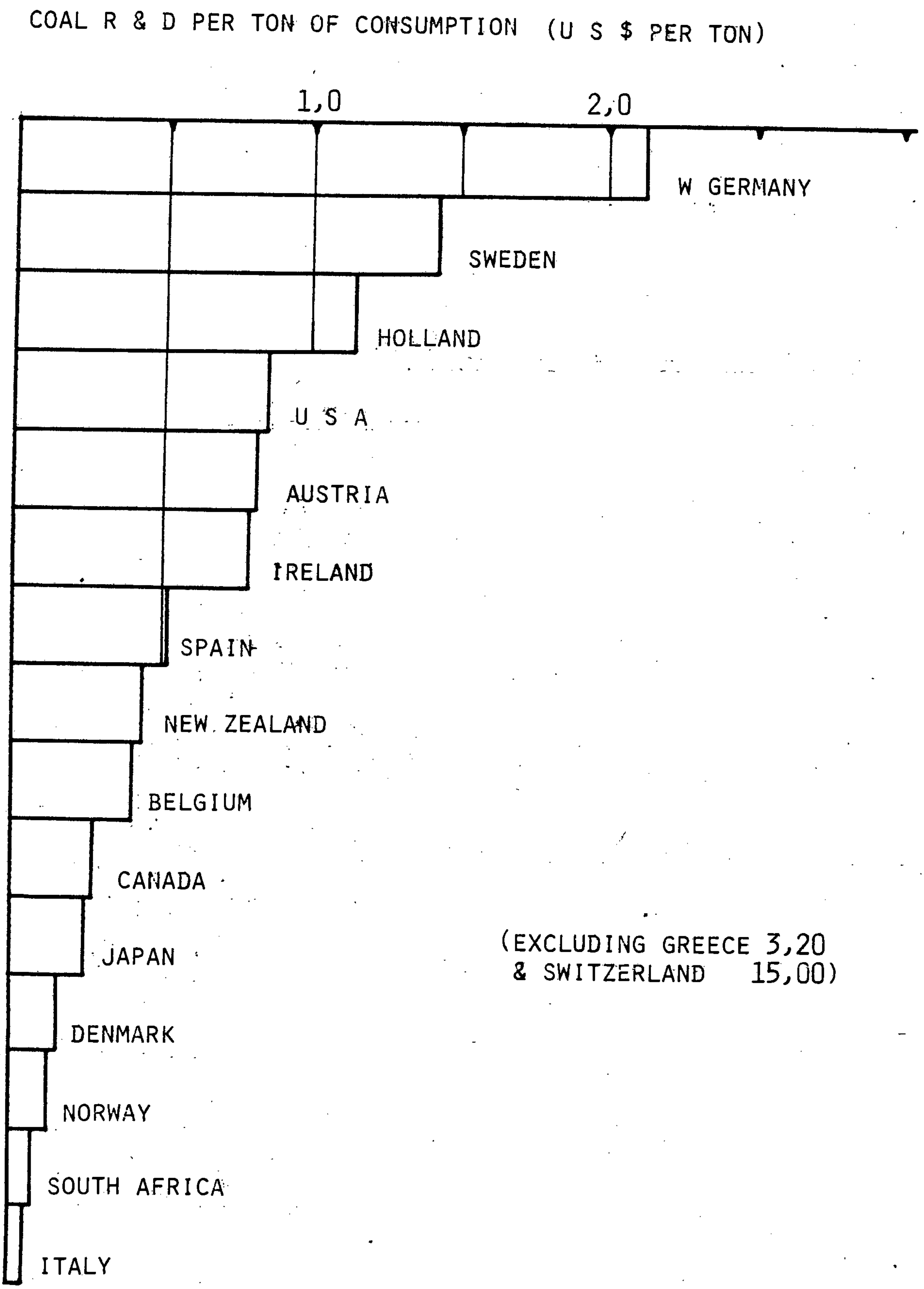


FIGURE 4 : GOVERNMENT R & D FUNDING ON COAL FOR 1979

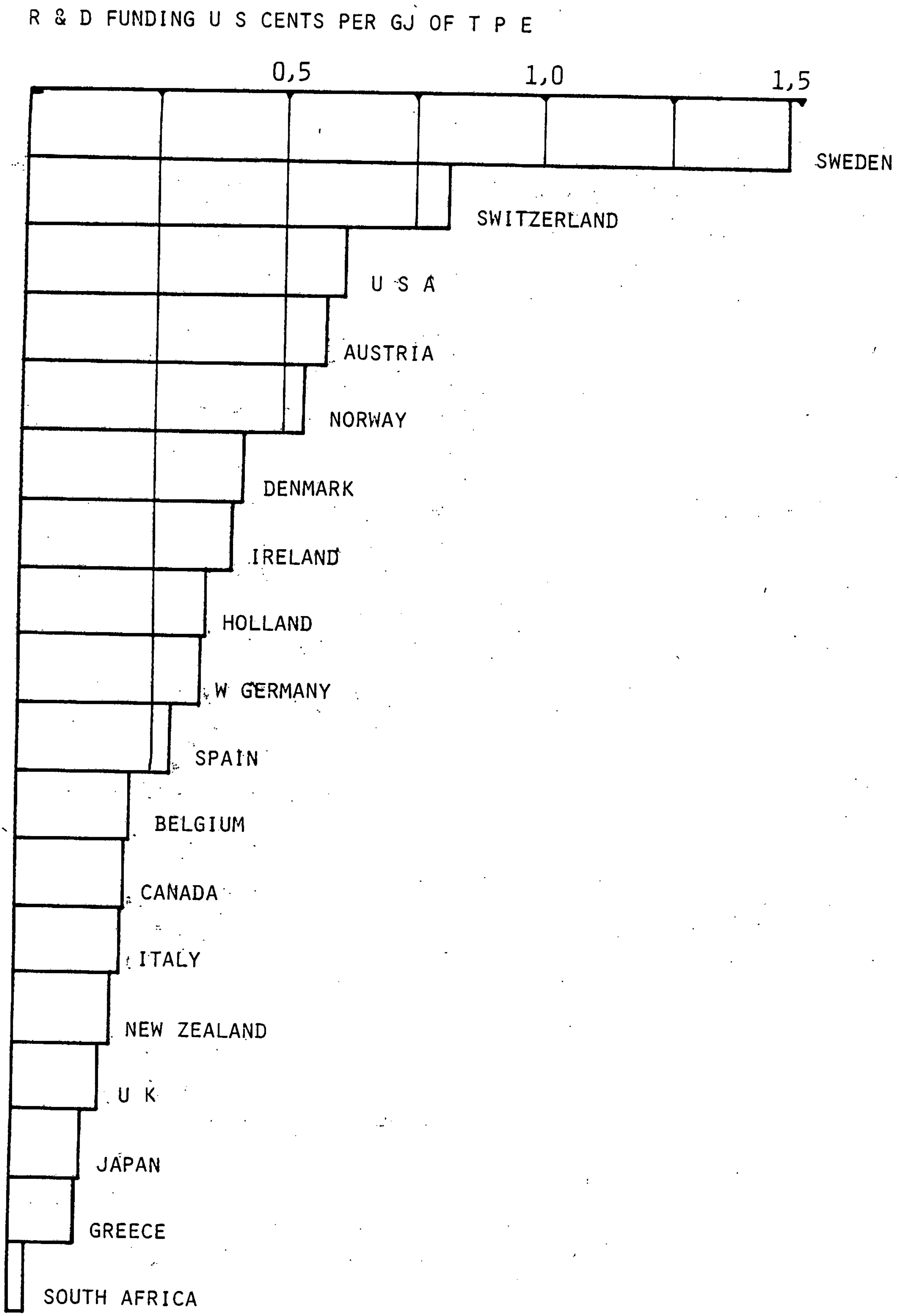


FIGURE 5 : GOVERNMENT R & D FUNDING ON RENEWABLE ENERGY IN 1979

REPORT NO. 35

FUNDING ON ENERGY RESEARCH AND DEVELOPMENT IN SOUTH AFRICA

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