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AN INITIAL MULTI-NATIONAL STUDY
OF
FUTURE ENERGY SYSTEMS
AND
IMPACTS OF SOME EVOLVING TECHNOLOGIES

MASTER

March 25, 1977

Jointly Prepared By:

BROOKHAVEN NATIONAL LABORATORY
Upton, NY 11973 USA

and

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ABSTRACT

Participants* from thirteen member nations of the International Energy Agency and the Commission of European Communities have been conducting co-operative energy systems analyses, the goal of which is to evaluate the possible impacts of new and conservation technologies. Such studies are intended to provide analytical bases to aid future decisions on cooperative research and development projects.

In the initial studies, a quantitative description of the 1974 energy system has been prepared for each participating nation. The "Group of 13" nations accounted for approximately half of the world energy consumption in 1974. It imported more than 30% of its primary energy requirements from other nations of the world. Oil and natural gas supplied almost 3/4 of the energy.

*The participants are from: Belgium, Canada, Denmark, Germany, Ireland, Japan, Norway, the Netherlands, Spain, Sweden, Switzerland, United Kingdom, and the United States. These nations are subsequently referred to as the "Group of 13". The host institutions for the collaborative effort are Brookhaven National Laboratory (Upton, New York, U.S.A.) and Kernforschungsanlage Jülich (Jülich, Germany).

Reference projections have been made for the years 1985 and 2000 to provide base cases for studies of the impacts of new and conservation technologies. Although these projections are not intended to be forecasts, taken together they indicate an increasing gap between the demand for energy and foreseeable domestic supplies, thus underscoring the urgency for the vigorous introduction of new energy technologies as well as the need for strong efforts in energy conservation. Some preliminary evaluations of selected technologies were made as a function of current development plans. None of these technologies taken individually appears capable of balancing the demand-supply equation.

A second phase of the project beginning in early 1977 will carry out more detailed analyses and will assess many additional technologies.

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FOREWORD

In February 1976, the IEA Steering Group on Systems Analysis (now called the Steering Group on Energy R&D Strategy) adopted plans for an IEA Systems Analysis Project, including a detailed work plan for Phase I of the activities. The objective of the project was to develop quantitative data on existing and projected energy systems of the IEA member nations, and to evaluate new and more efficient energy technologies so as to provide a basis for developing a cooperative energy R&D strategy for the IEA nations.

The project was to be conducted at two locations, Brookhaven National Laboratory (BNL) in the United States and Kernforschungsanlage Jülich (KFA) in the Federal Republic of Germany. Nations desiring to participate in the study were to send representatives to one or the other sites to conduct the studies.

A preliminary meeting of the prospective participating staffs was convened at KFA on March 22-23, 1976. The supporting staffs and first national participants assembled at BNL and KFA in early May 1976 to begin the studies, although some national participants arrived at later dates.

The Phase I tasks must be regarded as a preliminary stage to collect basic data and to demonstrate the practicality and benefits of a multi-national collaborative effort on energy systems analysis. Essentially, all of the tasks contained in the Phase I Work Plan were completed by the end of January 1977.

This report presents the data which have been compiled and such conclusions as can be drawn from the data at this early stage of the work.

It must be emphasized that the projections used in this document are not forecasts. They have been developed by the IEA Systems Analysis Projects at the two participating Laboratories to serve as a basis for assessing the impact of new supply and conservation technologies and, accordingly, they may deviate from official national projections. The projections have not received official endorsements and must be regarded as creations of the systems analysis staff. They are, by nature, hypothetical examples of the system configurations given no new major developments.

The methods used for projecting have varied from one country to another. In general, major uncertainties exist as to the validity of the projections. Particularly substantial additional effort will be required to better understand future energy demand. This will be an important task during Phase II. For the present reference projections in Phase I, no new technologies have been included, except in cases where national plans or policies assume their introduction. In some cases, various amounts of energy conservation have been taken into account, depending on announced national plans and policies. For these reasons, the projections must not be interpreted as probable descriptions of the future.

Throughout this period, attempts have been made to coordinate closely the work being carried out at the two locations. Although some differences in

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approach have been inevitable (and, indeed, useful), we believe that the collaboration has produced a reasonably uniform and unique result.

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Finally, we must acknowledge the essential contributions of the participants themselves, who on extremely short notice moved from their home countries to BNL or KFA to work harmoniously under great pressure despite language difficulties and often under conditions of severe personal inconvenience. The spirit of mutual cooperation has made this multi-national collaboration a rewarding experience for the two project directors.

DISCUSSION OF DATA

1. 1974 ENERGY SYSTEMS

1.1 Supply Sectors:

In 1974, the "Group of 13" participating countries¹⁾ required a total primary energy input²⁾ of 132×10^{18} joules. The fuel mix and the amounts of domestic production and imports are shown in Table 1 (all summary tables follow Section 2 beginning on page 10). A more detailed summary is given in Table 2.

Energy balance tables (the "Reference Energy Balance Format" -- REBF) and energy flow diagrams (the "Reference Energy System" diagrams -- RES) were prepared for each nation. Because of the large quantity of such material, the REBF tables and RES diagrams have not been included in this document.³⁾ Such tables and diagrams give a detailed quantitative representation of the energy flows in each national energy system.

- 1) The "Group of 13" participants are Belgium, Canada, Denmark, Germany, Ireland, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and the United States.
- 2) Non-fossil energy inputs have been calculated on the basis of the fossil fuel substitution principle, using substitution factors appropriate for each country.
- 3) Such tables and diagrams have been compiled in the form of national data appendices for the individual nations. Copies for specific nations can be obtained upon request from either of the project directors.

It can be seen from Tables 1 and 2 that in 1974 approximately half (51.0%) of the total primary input was based on oil, and that oil and gas together (petroleum)⁴⁾ provided almost 3/4 (73.6%) of the primary energy input.

Almost 1/3 (30.8%) of the primary energy input was net import from outside the Group. Only Canada and the Netherlands were net exporters of energy. The remaining eleven nations all required substantial net imports to balance their energy budgets. In the case of six countries, more than 2/3 of their primary energy supply was imported. Nine countries imported more than half of their energy.

The United States alone consumed almost 3/5 (57.9%) of the energy used by the Group. Although only 15.9% of the U.S. energy was imported, this amount constituted almost 1/3 (29.9%) of the total net import of the Group.

For the Group, indigenous production of crude oil was only about 2/5 (40.2%) of the oil consumed. There was a small net export of natural gas.

Thus, the 1974 energy systems of the Group were marked by two primary features: 1) the heavy dependence on petroleum (73.6%), and 2) the large net import of energy, of which 99.1% was crude oil and refined oil products.

1.2 Indigenous Resources:

The resources and reserves indigenous to the Group are summarized in a separate preliminary

- 4) We shall adopt the convention of the geologist and refer to oil and natural gas as "petroleum".

report⁵⁾ which also makes comparisons with world reserves and resources. Some of the principal findings are summarized in the following paragraphs.

Coal: Recoverable reserves of hard and brown coal indigenous to the IEA nations amount to approximately 53% of the world recoverable reserves (weighted for energy content). The energy content of the IEA recoverable reserves is approximately 60 times the total primary energy input for 1974 for the Group, or about 327 times the actual 1974 coal consumption of the Group.

The coal reserves are unevenly distributed among the Group, being concentrated primarily in the United States (62.1%), United Kingdom (19.3%), and Germany (13.9%).

Crude Oil: Recoverable reserves of crude oil indigenous to the IEA nations comprise only about 8 to 10% of the world total. The energy content of Group recoverable reserves is equivalent to 2.6 times the 1974 total primary energy input of the Group or 5.2 times the 1974 Group oil consumption.

The crude oil reserves of the Group are unevenly distributed, being concentrated within the United States (67.0%), the United Kingdom (13.0%), Canada (12.9%), and Norway (6.0%). The North Sea reserves of the United Kingdom and Norway which are just entering the early stages of exploitation will have a marked favorable effect on the energy budgets of those two nations in the two or three decades ahead. However, these are too small to

5) Preliminary Resource Appendix, Resource Evaluation of IEA Countries, revised, Jan. 31, 1977.
(Copies may be obtained from either of the project directors.)

have a major impact on the Group as a whole.

Natural Gas: Recoverable reserves of natural gas indigenous to IEA nations comprise approximately 19% of the world total. The energy content in the recoverable reserves of the Group is equivalent to only 3.9 times the 1974 total primary energy input of the Group, or to 17 times the 1974 consumption of natural gas by the Group.

The natural gas reserves are unevenly distributed, being concentrated in the United States (55.2%), Canada (18.9%), the Netherlands (13.5%), the United Kingdom (6.5%), and Norway (4.0%).

Uranium: Reasonably assured resources of uranium in the categories \$30/lb or less, indigenous to the IEA members, comprise about 58% of the world total (not counting the USSR, Eastern Europe, and China, for which data are not available). When consumed in non-breeder reactors, this reserve is equivalent to about 520×10^{18} joules or about 3.9 times the 1974 total primary energy consumption of the Group, or about 234 times the 1974 nuclear energy consumed by the Group in 1974.

The uranium reserves are unevenly distributed within the Group, being concentrated in the United States (54.1%), Canada (23.7%), Sweden (12.2%), and Spain (8.5%).

Other Fossil and Mineral Resources: Other fossil and mineral resources, not yet exploited to any large extent, are of interest because of their potential. As these are not yet in large scale production, the terminology, "recoverable reserves", has no meaning. Among such deposits are bituminous sands, oil shale, thorium, and lithium. These have been only briefly treated in the resource appendix,

but will be the subject of more intensive evaluation in future work.

Renewable Resources: Renewable resources (hydropower, geothermal, solar, wind, waves, biomass, etc.) must be treated differently than fossil or nuclear resources. The resource appendix discusses the problem of how the two classes of resources, non-renewable and renewable, might be compared. In the case of renewable resources, two quantities can be envisaged: 1) the total quantity of renewable resource available in a given region (e.g., the total annual insolation on a particular country) and 2) the theoretical "collectable resource base" (which would be somewhat analogous to practicably recoverable reserves for mineral fuels). The latter quantity is of most practical interest. Unfortunately, except for hydro, it appears definable only in terms of special collector devices which are the subject of several new technologies; e.g., wind generators, solar collectors, etc. This will be the subject of more intensive investigation in the future program.

Extensive data on renewable resources exist only for hydropower and wood. The resource appendix presents data on hydropower, which is an important component for several countries of the Group. However, as can be seen from Table 1, these contribute only 6.4% of the 1974 primary energy input for the Group. The appendix also includes average insolation data.

Some Comments on Resource Data: In general, the definitions of "recoverable resources", "total reserves", "total resources", etc., are imprecise and subject to much confusion. Improvement in the definition and classification of resources is outside the scope of our tasks; however, we note that

much effort in this area is needed and should be encouraged.

In particular, "recoverable reserves" are a function of the price of the commodity in addition to the geological factors. We have not been able to locate much information on this important subject. It appears that most reliable information on this subject, if indeed it exists at all, is treated as proprietary data by the energy producing industries.

1.3 Demand Sectors:

Final Energy Consumption: The energy actually consumed in the demand sector is often called the Final Energy Consumption (FEC).⁶⁾ This quantity is less than the Primary Energy Consumption (PEC) by the amount of losses which occur in processing, refining, converting, transporting, transmitting and distributing, and consumption for non-energy uses. The FEC is of fundamental interest because:

- FEC represents the energy actually used to perform useful services in the economy;
- For each consuming sector, the FEC fuel mix gives an indication of the possibilities of interfuel substitution; and
- Efficiencies in the FEC disclose conservation opportunities in the end uses.

The numerical relationship between PEC and FEC can be derived by two general methods:

- 6) We shall adopt the OECD usage and use the terminology: Final Energy Consumption (FEC) = Total Final Consumption (TFC) minus non-energy uses.

1. the physical principle, or
2. the fossil-fuel equivalence principle.

These methods give different values for the non-fossil primary energy inputs, but are identical in the fossil-fuel sectors.

The physical principle tabulates the actual energy input for hydroelectric power, nuclear, geothermal, solar, wind, etc. This approach is valuable and necessary in engineering design, calculating environmental factors, etc. However, it is less useful for studies which address the problem of reducing dependence on petroleum supplies.

The fossil fuel equivalence principle uses the FEC to derive a fictitious PEC that would be required if that particular energy flow were provided by fossil fuels. In particular, if electricity, district heat, or process heat were supplied from hydro, nuclear, geothermal, respectively, the primary energy would be calculated as the amount of fossil fuel required to provide the same final energy. We have used this principle in deriving the primary energy data which are listed in the tables and data appendix. The conversion factors used for each country are those adopted by the OECD for 1974⁷⁾ which reflect the average national efficiency for the inventory of base-loaded steam-electric plants of that country (there are a few exceptions which emphasize special systems configurations).

Employment of the fossil fuel equivalence principle to calculate primary energy input gives data

7) OECD, Energy Balance of the OECD Countries, 1960-1974, Paris, 1976.

of greatest value to IEA planning, because it displays the quantities of petroleum or coal that would be needed to replace a given non-fossil supply sector. The actual physical flow of energy through a non-fossil system from source to output is of little interest to the decision maker dealing with the oil dependence problem. The central question is how much more oil or coal would be needed if a given non-fossil supply technology failed to develop according to expectation.

Of course, for evaluation of the technical aspects of a given technology, it is necessary to use the physical principle. For example, to calculate the net energy output for a solar or wind conversion system, the input energy, net efficiency, etc., must be calculated from the actual physical insolation or air flow rates, and the physical characteristics of the system.

From the above discussion, it can be seen that we regard TFC and FEC as more fundamental properties of the system than PEC. For our studies, we wish to emphasize the advantages of focusing attention on both final and primary energy consumption rather than on primary alone.

Distribution of FEC Among Demand Sectors: The data pertaining to FEC appear later in the report (Tables 12-18). In 1974, the FEC "patterns" vary widely within the Group. The term "patterns" embraces the FEC ratios in the three sectors: industry, residential and commercial, and transportation. Given are the fuel mixes and FEC per capita within each sector.

For example, the FEC/capita in industry ranged from 22 to 87 x 10⁹ joules/capita, reflecting the composition and energy intensiveness of heavy

industry. In the residential and commercial sectors, the range was from 10 to 95 x 10⁹ joules/capita, reflecting different climates, architecture, and comfort standards. In the transportation sector, most countries were in the range of 20 x 10⁹ joules/capita but Canada and the United States showed anomalously high per capita values of 62 and 91 respectively. In terms of FEC, the USA used 37.2% of its energy for transportation, whereas Sweden used only 16.0%. Within the Group, the total final consumption (TFC) ranged from 50 to 264 x 10⁹ joules/capita.

The data files of the individual national participants contain extensive demand sector data at higher levels of disaggregation which will be of great value in the Phase II studies; for example, specific energy for industrial output (joules per ton of steel), variations in thermal efficiency of various building types, etc. More detailed international comparisons will be possible in the Phase II studies which will be helpful in identification of opportunities for improved efficiencies, in broader adoption of successful technologies, and in cooperative R&D efforts.

2. REFERENCE PROJECTIONS FOR 1985 AND 2000

2.1 Purpose:

In order to evaluate the impact of new and conservation technologies, it is necessary to devise "reference projections" which describe energy systems configurations at future times. For technologies that require research and development, the times of greatest interest lie some distance in the future, e.g., 1985, 2000, and beyond. It must be recognized that a variety of uncertainties preclude the construction of precise configurations a decade or more in the future. Nevertheless, given reasonable sets of assumptions, projections can be constructed which can serve as adequate reference cases for conducting the perturbation analyses. The projections which we present are intended to serve this purpose and this purpose alone. They are not forecasts.

2.2 Limitations:

Several basic limitations in our "reference projections" should be noted:

a) In most cases, they are not official government projections. We have attempted to remain consistent with government projections when such projections were available. However, most governments prepare a broad range of projections, based on many sets of assumptions, and these are subject to frequent revision. Many such revisions have been made while our work was in progress. Our projections have not received official endorsements, and must be regarded as creations of the systems analysis staff.

b) Unfortunately, it has not been possible at this stage of the work to achieve complete consistency with other IEA and OECD activities which

have been under way simultaneously. Such refinements will be made as quickly as possible in the next phase of our work.

c) It must be emphasized that our "reference projections" are not intended to be forecasts of the most probable evolution of the energy systems. Rather, they are hypothetical descriptions of the future based on knowledge of past trends and constrained by a variety of specific assumptions which are not necessarily the most probable.

d) It has not been possible to adopt uniform procedures for making our reference projections. Each of the participants was constrained to use methods traditional to his home country. Therefore, direct comparison between countries is not strictly valid and caution should be used in making such comparisons.

2.3 Underlying Assumptions:

Certain assumptions about the growth rate of population and gross domestic product (GDP), energy-GDP elasticity, etc., are inherent in all energy systems projections whether expressed explicitly or contained implicitly in more general assumptions. The methods used have varied from country to country. An attempt has been made to identify and quantify the above major underlying assumptions for each projection whether explicit or implicit. For several countries, "High" and "Low" cases have been prepared, which employ two different sets of underlying assumptions. Unfortunately, it has not been possible to define uniform "High" and "Low" cases for all countries.

In some, but not all, cases where national plans or policies provide for the introduction of new or conservation technologies or for expansion of

existing systems, such technologies have been incorporated in the projections. Otherwise new technologies generally have been omitted, since their impacts on the energy systems are to be studied as perturbations of the base cases.

Substantial amounts of policy- and price-induced conservation and improved efficiency in energy usage are embodied in some projections. However, we have not been able to find a meaningful way to express the amounts in summary form. This component is discussed for individual national projections in the national data appendices.³⁾ In several cases the projections are made on a straightforward basis, considering neither conservation measures nor saturation effects. Thus, the projections mark the upper level of demand for energy.

The balance between demand and supply has been achieved partly through plausible assumptions about exploitation of indigenous resources, but mostly by the assumption of oil imports to eliminate the deficit. It has been assumed that no unexpected constraints on domestic or imported fuel supplies arise.

A brief description of the methods and assumptions used in the projections for each country can be found in the data appendices of the individual countries.³⁾ The principal indicators (population and GDP growth rates, consumption elasticities, etc.) appear in Tables 3 and 4.

The anticipated population growth rate is small, being almost zero or even slightly negative for five of the countries. For the Group, the total population increase for the period 1974 to 1985 is only 8%, and for 1974 to 2000 only about 18%.

The assumed (or implied) growth in national GDP varies widely among the countries in the Group, ranging from a low of 1.4% per year to a high of more than 6% per year (see Table 3). The PEC elasticities⁸⁾ associated with the projections range from 0.2 to 2.0. The PEC elasticity is a rough measure of the change in energy intensity of a national economy. However, considerable judgment must be exercised in the interpretation of the significance of trends in the PEC elasticity, because this quantity is derived from two highly aggregated sets of data, i.e., the PEC and GDP growth rates. Each of these is influenced by many factors which might or might not affect the coupling between energy and the economy. For example, trends in the PEC are affected by fuel mixes, conversion technologies and efficiencies, conservation measures, etc. Also apparent changes in PEC can result from different methods used in calculating the non-fossil components, e.g., whether the fossil equivalent or the physical principles are used.

Often the data for TFC provide a better basis for comparison of development between different countries. It can be seen from Table 4 that all countries of the Group (except Norway) project an elasticity of electrical consumption greater than unity. This indicates not only a higher growth rate for the electrical industry than for the general economy but also a higher market share for electricity at the TFC level in future years. The shift toward greater electrification can be seen when comparing both the TFC and electrical consumption elasticities.

8) Elasticities may be defined respectively, for PEC, TFC, and electricity consumption (ELC) at final demand as follows: $\frac{\Delta \text{PEC}}{\text{PEC}} / \frac{\Delta \text{GDP}}{\text{GDP}}$; $\frac{\Delta \text{TFC}}{\text{TFC}} / \frac{\Delta \text{GDP}}{\text{GDP}}$; $\frac{\Delta \text{ELC}}{\text{ELC}} / \frac{\Delta \text{GDP}}{\text{GDP}}$.

2.4 Discussion of the Projections:

The Group composite primary energy inputs for 1985 and 2000 are shown in Tables 5 and 6. These summaries are based on the more detailed data in Tables 7 and 8 which give the projected primary energy input by country and fuel.

As can be seen from the tables, the demand for primary energy increases steadily compared with the 1974 level, which results in a consumption greater by a factor of 1.4 in 1985 and of 2.2 in 2000.

Since the population growth is anticipated to be small, most of the increase in demand must be attributed to a large increase in primary energy consumption per capita; i.e., between 1974 and 2000, the per capita consumption is projected to almost double (see Table 16). Part of this increase can be accounted for by heavier electrical consumption per capita (see Table 16), since the shift to electrification requires a larger input of primary energy. However, the bulk of the increase must be ascribed to the aspiration for a higher standard of living, i.e., the growth of the national economies.

It is appropriate at this point to remind the reader again that the projections, in general, do not take account of the introduction of new technologies or the reductions brought about by conservation technologies or measures (unless such technologies/measures are definitely incorporated into national planning). Thus, the projected demands reflect the situation that would prevail in the absence of new/conservation technologies. For such a hypothetical situation, the total import and oil import requirements would be as shown in Table 9.

Without successful introduction of new technologies, the Group would require approximately 110×10^{18} joules per year of indigenous and imported oil by the end of the century in order to meet economic growth aspirations. It should be noted that total world production of oil at the present time (approximately 56 million barrels/day) is equivalent to about 124×10^{18} joules per year. Thus, without successful new or conservation technologies, the Group would require as much oil as the present world production to balance its energy budget. The projected demand for imported oil increases with time from 40×10^{18} joules per year in 1974 to 53 and 74×10^{18} joules per year in 1985 and 2000 respectively.

The collective production of indigenous energy for the Group is projected to increase substantially for all conventional fuels, except for natural gas. The ratio of production in year 2000 to 1974 production is as follows:

<u>Energy Form</u>	<u>Indigenous Production</u>
	<u>Ratio 2000/1974</u>
Oil	1.3
Natural Gas	0.8
Coal	2.1
Nuclear ⁹⁾	28.2
Hydro	1.7

- 9) The supply of nuclear electricity has been generally treated as "domestic" (except for Switzerland). For the Group as a whole, the aggregated result is not unreasonable, because, as a first approximation, the IEA Group is expected to produce most of the uranium it will consume between now and 2000, thus net imports into the Group will be small. In the Phase II Program, the details of the flow of resources between IEA countries required by the nuclear cycle will be analyzed more fully.

Oil production is assumed to increase by 30%, mostly from the North Sea region. Nuclear, starting from a relatively small level in 1974, is projected to increase by almost a factor of 30, and by 2000 would yield more total energy than coal. Although coal production is assumed to double and sufficient reserves exist in the IEA member countries to meet total IEA demand, the summation of projected coal imports and exports indicates a steadily increasing net import into the IEA group. This large and long term deficit might be an appropriate subject for more detailed investigation.

Even if the above increases are realized, indigenous production fails to keep pace with growth in demand.

TABLE 1

1974 PRIMARY ENERGY INPUT FOR THE "GROUP OF 13"

ENERGY FORM	INDIGENOUS PRODUCTION		NET IMPORT ¹⁾		TOTAL PRIMARY ENERGY CONSUMPTION	
	10 ¹⁸ joules	Per-cent ²⁾	10 ¹⁸ joules	Per-cent ²⁾	10 ¹⁸ joules ³⁾	Per-cent ⁴⁾
COAL ⁵⁾	23.789	97.8	0.541	2.2	24.330	18.4
OIL ⁶⁾	27.027	40.2	40.234	59.8	67.261	51.0
NATURAL GAS	30.102	100.8	-0.247	-0.8	29.855	22.6
HYDRO ⁷⁾	7.975	99.9	0.008 ⁸⁾	--	7.982	6.0
NUCLEAR ^{7,9)}	2.147	96.7	0.074	3.3	2.221	1.7
OTHER ¹⁰⁾	0.351	100	--	--	0.351	0.3
TOTALS	91.0391	69.2	40.610	30.8	132.001	100 ¹¹⁾

1) Net import = import - export - bunkers (negative value indicates net export).

2) Percent of given fuel.

3) This column is the sum of indigenous production plus net imports and might be slightly different from the actual total primary energy consumption because of stockpiling.

4) Percent that individual energy forms contribute to the total primary energy consumption.

5) Coal and coal products.

6) Crude oil and oil products, including natural gas liquids.

7) Calculated on the basis of equivalent amount of fossil fuels required to generate an equal net amount of electricity in a steam-electric plant of average efficiency (for each nation for 1974). These equivalent efficiencies lie in the range of 30-40%. The corresponding physical efficiencies lie in the following ranges: hydro, 80-90%; nuclear, 32-33%; geothermal, 14-15%.

8) Imported electricity regardless of origin.

9) All nuclear is treated as "domestic", except for Switzerland, which classified nuclear as "imported".

10) "Other" implies: geothermal, wood, peat, solar, etc. Where appropriate, note (7) applies.

11) Total not exactly 100% due to rounding decimals.

TABLE 2
1974 PRIMARY ENERGY INPUT BY NATION AND FUEL
(10¹⁸Joules)

NATION	COAL		OIL		NATURAL GAS		HYDRO	NUCLEAR	ELECTRIC IMPORT	OTHER	TOTALS		TOTAL PRIMARY ENERGY CONSUMP. ³⁾
	Domestic	Import	Domestic	Import	Domestic	Import	Domestic	Domestic ¹⁾	Import ²⁾	Domestic	Domestic	Import ⁴⁾	
BELGIUM	0.216	0.294	--	1.085	0.002	0.355	0.007	0.001	-0.003	--	0.226	1.731	1.900
CANADA	0.522	0.082	4.301	-0.506	2.598	-0.998	2.343	0.155	-0.047	--	9.919	-1.469	8.450
DENMARK	--	0.095	0.004	0.688	--	--	--	--	--	0.007	0.011	0.783	0.729
GERMANY	3.787	-0.648	0.261	5.414	0.670	0.697	0.160	0.119	0.058	0.050	5.047	5.521	10.720
IRELAND	0.002	0.025	--	0.239	--	--	0.009	--	--	0.043	0.054	0.264	.316
JAPAN	0.585	2.065	0.030	10.976	0.112	0.213	0.870	0.215	--	0.044	1.856	13.254	14.815
NETHERLANDS	0.022	0.097	0.066	1.084	2.966	-1.543	--	0.035	-0.016	0.012	3.101	-0.378	2.659
NORWAY	0.013	0.028	0.073	0.244	0.001	--	0.481	--	-0.035	--	0.568	0.237	0.804
SPAIN	0.311	0.099	0.081	1.714	--	0.035	0.325	0.076	-0.012	--	0.793	1.836	2.629
SWEDEN	--	0.074	--	1.110	--	--	0.536	0.018	0.028	0.147	0.701	1.212	1.914
SWITZERLAND	--	0.013	--	0.584	--	0.015	0.116	0.074 ¹⁾	-0.011	0.020	0.136	0.675	0.792
U.K.	2.875	0.007	0.018	4.777	1.376	0.026	0.054	0.375	0.001	--	4.698	4.811	9.496
U.S.A.	15.456	-1.690	22.193	12.825	22.377	0.953	3.074	1.153	0.045	0.028	64.281	12.133	76.414
"GROUP OF 13"	23.789	0.541	27.027	40.234	30.102	-0.247	7.975	2.221	0.008	0.351	91.391	40.610	131.638

1) All nuclear is treated as "domestic", except for Switzerland which classifies nuclear as "imported".

2) Electricity Import

3) This column is the actual total primary energy consumption and not necessarily equal to the sum of the preceding two columns due to stockpiling.

4) Net import equals import minus export minus bunkering.

TABLE 3

POPULATION AND GDP INDICATORS ASSOCIATED WITH THE DEMAND PROJECTIONS

NOTE: The national demand and supply projections for 1985 and 2000 have been made by IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.

NATION	POPULATION (Millions of Persons)			POPULATION GROWTH RATE (% Per Year)			GROSS DOMESTIC PRODUCT ABSOLUTE ¹⁾ . GROWTH RATES ²⁾ (10 ⁹ \$) (% Per Year)		
	1974	1985	2000	1974/1985	1985/2000		1974	1974/1985	1985/2000
BELGIUM a) b)	9.79	9.8	9.8	0	0		53.4	3.0	2.5
								4.0	3.5
CANADA c)	22.5	26.0	30.9	1.32	1.17		145.3	4.51	3.19
DENMARK a) b)	5.05	5.2	5.3	0.27	0.13		30.4	4.0	3.5
								4.0	3.5
GERMANY a) b)	62.05	59.6	58.5	-0.37	-0.12		384.9	3.0	2.8
								3.7	3.5
IRELAND c)	3.09	3.5	4.2	1.25	1.25		6.7	3.0	3.0
JAPAN c)	110.05	123.3	135.2	1.04	0.62		455.5	5.96	4.0
NETHERLANDS a) b)	13.5	13.9	14.4	0.27	0.24		69.6	2.2	2.2
								3.4	2.9
NORWAY ³⁾ c)	3.99	4.2	4.4	0.39	0.33		23.2	4.2	3.8
SPAIN c)	35.13	39.0	45.0	0.96	0.95		85.6	4.7	4.0
SWEDEN c)	8.2	8.3	8.5	0.15	0.15		56.1	3.0	2.7
SWITZERLAND a) b)	6.4	6.5	6.6	0.14	0.14		47.3	1.4	2.4
								1.4	2.4
UNITED KINGDOM a) b)	56.06	56.7	57.5	-0.1	0.1		189.0	2.0	2.0
								3.0	3.0
UNITED STATES c)	211.89	234.5	263.8	0.9	0.8		1411.3	3.13	2.4
TOTALS "GROUP OF 13"	547.7	590.5	644.1	0.69	0.58		2958.3	--	--

a) Low Case b) High Case c) Base Case

- 1) Gross Domestic Product in 1974 U.S. Dollars. Values in local currency taken from National Accounts of OECD Countries, 1974, Vol. II, Statistics Division OECD, Paris. Average 1974 exchange rates were applied (Source: German Federal Bank).
- 2) For all countries except Sweden and United States, assumptions concerning GDP growth rates have been used in the demand projections.
- 3) Petroleum activity in the North Sea not included in the GDP growth rates.

TABLE 4

RATIO OF PRIMARY ENERGY CONSUMPTION TO GDP AND CONSUMPTION ELASTICITIES ASSOCIATED WITH DEMAND PROJECTIONS

(NOTE: The national demand and supply projections for 1985 and 2000 have been made by IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.)

		RATIO OF PRIMARY ENERGY CONSUMPTION TO GDP (10 ¹⁸ Joules/10 ⁹ \$)			PRIMARY ENERGY CONSUMPTION ELASTICITY (1)		TOTAL FINAL CONSUMPTION ELASTICITY (2)		ELECTRICITY CONSUMPTION ELASTICITY (3)	
		1974 ^{d)}	1985	2000	1974/1985	1985/2000	1974/1985	1985/2000	1974/1985	1985/2000
BELGIUM	a)	0.0356	0.0332	0.0339	0.78	1.06	0.82	0.97	1.14	1.86
	b)		0.0344	0.0349	0.92	1.03	0.92	0.96	1.32	1.32
CANADA	c)	0.0583	0.0514	0.0493	0.74	0.91	0.70	0.91	1.33	1.28
DENMARK	a)	0.0238	0.0186	0.0161	0.41	0.72	0.41	0.79	1.12	0.87
	b)		0.0224	0.0220	0.78	0.97	0.80	1.02	1.21	1.10
GERMANY	a)	0.0278	0.0271	0.0271	0.91	0.99	0.79	0.63	1.59	1.82
	b)		0.0267	0.0280	0.89	0.96	0.79	0.67	1.47	1.64
IRELAND	c)	0.0470	0.0498	0.0531	1.36	1.17	0.95	1.06	2.25	1.80
JAPAN	c)	0.0325	0.0324	0.0360	0.98	0.994	0.97	0.88	1.10	1.369
5) NETHERLANDS	a)	0.0382	0.0384	0.0368	1.01	0.89	1.16	0.83	1.16	1.05
	b)		0.0425	0.0403	1.30	0.89	1.41	0.85	1.32	1.15
NORWAY ⁵⁾	c)	0.0490	0.0278	0.0273	0.89 ⁴⁾	0.86 ⁴⁾	0.94	0.84	0.70 ⁴⁾	0.87 ⁴⁾
SPAIN	c)	0.0307	0.0352	0.0455	1.28	1.44	1.19	1.27	1.96	1.97
SWEDEN ⁵⁾	c)	0.0341	0.0361	0.0308	1.18	0.60	0.91	0.43	1.94	1.13
SWITZERLAND ⁽⁶⁾	a)	0.0167	0.0195	0.0198	2.03	1.04	1.43	0.80	2.61	1.14
	b)		0.0195	0.0213	2.02	1.25	1.71	1.20	1.91	0.92
5) UNITED KINGDOM	a)	0.0502	0.0421	0.0381	0.19	0.66	0.19	0.51	1.15	1.43
	b)		0.0422	0.0376	0.46	0.74	0.40	0.63	1.26	1.33
UNITED STATES ⁵⁾	c)	0.0541	0.0534	0.0527	0.958	0.958	0.859	0.75	1.53	1.58

a) Low Case b) High Case c) Base Case d) Actual

1) Ratio of Primary Energy Growth Rate to GDP Growth Rate.

2) Ratio of Final Energy Consumption plus non-energy uses growth rate to GDP growth rate.

3) Ratio of Total Final Electricity Growth Rate to GDP Growth Rate.

4) Petroleum activity in North Sea not included.

5) Elasticities are not explicitly used in the projections. They have been derived afterwards from energy and GDP growth rates.

6) The low case for Switzerland takes into account a high level of substitution from oil to electricity.

TABLE 5

1985 PRIMARY ENERGY INPUT FOR THE "GROUP OF 13"¹⁾

ENERGY FORM	INDIGENOUS PRODUCTION		NET IMPORT ²⁾		TOTAL PRIMARY ENERGY CONSUMPTION	
	10 ¹⁸ joules	Per-cent ³⁾	10 ¹⁸ joules	Per-cent ³⁾	10 ¹⁸ joules	Per-cent ⁴⁾
COAL ⁵⁾	32.715	91.7	2.962	8.3	35,677	19.0
OIL ⁶⁾	33.319	38.4	53.561	61.6	86,880	46,3
NATURAL GAS	29.689	80.4	7.248	19.6	36,937	19.7
HYDRO ⁷⁾	10.519	99.2	0.081 ⁸⁾	0.8	10,600	5.6
NUCLEAR ^{7,9)}	16.440	98.5	0.246	1.5	16,686	8.9
OTHER ¹⁰⁾	0.858	100	--	--	0.858	0.5
TOTALS	123.540	65.8	64.098	34.2	187.638	100 ¹¹⁾

- 1) The national demand and supply projections for 1985 and 2000 have been made by IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.
- 2) Net import = import - export - bunkers (negative value indicates net export).
- 3) Percent of given fuel.
- 4) Percent that individual energy forms contribute to the total primary energy consumption.
- 5) Coal and coal products.
- 6) Crude oil and oil products, including natural gas liquids.
- 7) Calculated on the basis of equivalent amount of fossil fuels required to generate and equal net amount of electricity in a steam-electric plant of average efficiency (for each nation for 1974). These equivalent efficiencies lie in the range of 30-40%. The corresponding physical efficiencies lie in the following ranges: hydro, 80-90%; nuclear, 32-33%; geothermal, 14-15%.
- 8) Imported electricity regardless of origin.
- 9) All nuclear is treated as "domestic", except for Switzerland, which classified nuclear as "imported".
- 10) "Other" implies: geothermal, wood, peat, solar, etc. Where appropriate, note (7) applies.
- 11) Total not exactly 100% due to rounding decimals.

TABLE 6

2000 PRIMARY ENERGY INPUT FOR THE "GROUP OF 13"¹⁾

ENERGY FORM	INDIGENOUS PRODUCTION		NET IMPORT ²⁾		TOTAL PRIMARY ENERGY CONSUMPTION	
	10 ¹⁸ joules	Per-cent ³⁾	10 ¹⁸ joules	Per-cent ³⁾	10 ¹⁸ joules	Per-cent ⁴⁾
COAL ⁵⁾	50.261	85.2	8.712	14.8	58.973	20.6
OIL ⁶⁾	32.033	29.4	76.796	70.6	108.829	38.0
NATURAL GAS	25.568	67.2	12.457	32.8	38.025	13.3
HYDRO ⁷⁾	12.712	99.0	0.124 ⁸⁾	1.0	12.836	4.5
NUCLEAR ^{7,9)}	57.191	99.1	0.529	0.9	57.720	20.2
OTHER ¹⁰⁾	9.912	100	--	--	9.912	3.5
TOTALS	187.677	65.6	98.618	34.4	286.295	100 ¹¹⁾

- 1) The national demand and supply projections for 1985 and 2000 have been made by IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.
- 2) Net import = import - export - bunkers (negative value indicates net export).
- 3) Percent of given fuel.
- 4) Percent that individual energy forms contribute to the total primary energy consumption.
- 5) Coal and coal products.
- 6) Crude oil and oil products, including natural gas liquids.
- 7) Calculated on the basis of equivalent amount of fossil fuels required to generate and equal net amount of electricity in a steam-electric plant of average efficiency (for each nation for 1974). These equivalent efficiencies lie in the range of 30-40%. The corresponding physical efficiencies lie in the following ranges: hydro, 80-90%; nuclear, 32-33%, geothermal, 14-15%.
- 8) Imported electricity regardless of origin.
- 9) All nuclear is treated as "domestic", except for Switzerland, which classified nuclear as "imported".
- 10) "Other" implies: geothermal, wood, peat, solar, etc. Where appropriate, note (7) applies.
- 11) Total not exactly 100% due to rounding decimals.

TABLE 7
1985 PRIMARY ENERGY INPUT BY NATION AND FUEL¹⁾
(10¹⁸Joules)

NATION	COAL		OIL		NATURAL GAS		HYDRO	NUCLEAR	ELECTRIC IMPORT	OTHER	TOTALS		TOTAL PRIMARY ENERGY CONS.
	Domestic	Import	Domestic	Import	Domestic	Import	Domestic	Domestic	Import	Domestic	Domestic	Import ²⁾	
BELGIUM a)	0.205	0.304	--	1.280	--	0.474	0.013	0.180	--	--	0.398	2.058	2.456
BELGIUM b)	0.205	0.358	--	1.482	0.002	0.536	0.014	0.238	-0.005	--	0.459	2.371	2.830
CANADA c)	1.267	-0.222	5.151	1.911	3.346	-0.935	3.242	0.360	--	--	11.366	0.754	12.120
DENMARK a)	--	0.165	C.030	0.560	0.106	--	--	--	--	0.012	0.148	0.725	0.873
DENMARK b)	--	0.124	C.030	0.862	--	--	--	--	--	0.005	0.035	0.986	1.021
GERMANY a)	3.591	-0.405	C.114	6,096	0.703	1,985	0.149	2,069	0.103	0.043	6,669	7,779	14,448
GERMANY b)	3,758	-0.405	C.114	6,508	0.703	2,083	0.150	2,336	0.103	0.045	7,106	8,289	15,395
IRELAND c)	0.002	0.021	--	0.314	0.039	--	0.007	--	--	0.052	0.100	0.335	0.435
JAPAN c)	0.557	3.349	C.118	17.028	0.439	1.879	1.088	3.027	--	0.423	5.652	22.256	27.908
NETHERLANDS a)	--	0.199	C.063	1,699	3,057	-1.731	--	0.104	--	0.012	3,236	0.167	3,403
NETHERLANDS b)	--	0.289	C.063	2,393	3,069	-1,626	--	0.104	--	0.012	3,248	1,056	4,304
NORWAY c)	0.018	0.025	1.883	-1.373	0.992	-0.961	0.619	--	--	--	3.512	-2.309	1.203
SPAIN c)	0.585	0.193	C.190	1.986	0.300	0.080	0.483	1.185	--	--	2.743	2.259	5.002
SWEDEN c)	--	0.146	--	1.345	--	--	0.611	0.558	--	0.148	1,317	1.491	2.808
SWITZERLAND a)	--	0.017	--	0.584	--	0.087	0.305	0.246	-0.022	0.026	0.331	0.912	1.243
SWITZERLAND b)	--	0.008	--	0.680	--	0.062	0.305	0.194 ³⁾	-0.022	0.016	0.321	0.922	1.243
U.K. a)	2.990	--	4.800	-0.529	1.957	--	0.053	0.633	--	--	10.433	-0.529	9.904
U.K. b)	3.469	--	7.032	-2,117	1.922	--	0.053	0.672	--	--	13.148	-2,117	11.031
U.S.A. c)	23.500	-0.83	22.970	22.660	18.750	6.370	3.949	8.324	--	0.142	77.635	28.200	105.835
"GROUP OF 13" a)	32.715	2.962	35.319	53.561	29.689	7.248	10.519	16.686	0.081	0.858	123,540	64,098	187.638
"GROUP OF 13" b)	33,361	3.056	35,551	53,679	29,562	7,488	10,521	16,998	0.076	0.843	126,642	64,493	191.135

a) Low Case; b) High Case; c) Base Case

1) The national demand and supply projections for 1985 have been made by the IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.

2) Net import equals import minus export minus bunkering.

3) All nuclear is treated as "domestic", except for Switzerland which classifies nuclear as "imported".

TABLE 8
2000 PRIMARY ENERGY INPUT BY NATION AND FUEL¹⁾
(10¹⁶Joules)

NATION		COAL		OIL		NATURAL GAS		HYDRO	NUCLEAR	ELECTRIC IMPORT	OTHER	TOTALS		TOTAL PRIMARY ENERGY CONS. 2)
		Domestic	Import	Domestic	Import	Domestic	Import	Domestic	Domestic	Import	Domestic	Domestic	Import	
BELGIUM	a)	0.205	0.257	--	1.732	--	0.728	0.013	0.700	--	--	0.918	2.717	3.635
	b)	0.205	0.303	--	2.297	--	0.998	0.013	0.990	--	--	1.208	3.598	4.806
CANADA	c)	1.437	--	4.836	2.004	3.988	--	4.269	2.080	--	--	16.610	2.004	18.614
DENMARK	a)	--	0.249	0.005	0.801	0.193	--	--	--	--	0.019	0.217	1.050	1.267
	b)	--	0.207	0.005	1.472	--	--	--	--	--	0.005	0.010	1.679	1.689
GERMANY	a)	4.232	-0.405	0.063	7.395	0.703	1.926	0.148	7.468	0.103	0.047	12.661	9.019	21.680
	b)	4.563	-0.405	0.063	8.640	0.703	2.025	0.148	9.365	0.103	0.047	14.889	10.363	25.252
IRELAND	c)	0.002	0.116	--	0.452	--	--	0.007	0.095	--	0.053	0.157	0.568	0.725
JAPAN	c)	0.557	9.044	0.118	19.943	0.439	5.567	1.590	9.318	--	9.214	21.236	34.554	55.790
NETHERLANDS	a)	--	0.778	0.063	2.194	0.669	0.441	--	0.387	--	0.012	1.131	3.413	4.544
	b)	--	1.680	0.063	2.810	0.669	0.507	--	0.563	--	0.012	1.307	4.997	6.304
NORWAY	c)	0.030	0.032	2.260	-1.373	1.500	-1.454	0.945	--	--	0.010	4.745	-2.795	1.950
SPAIN	c)	0.650	0.518	3.440	2.870	0.600	0.483	0.743	5.300	--	0.027	7.760	3.871	11.631
SWEDEN	c)	--	0.191	--	1.400	--	--	0.645	1.185	--	0.150	1.980	1.591	3.571
SWITZERLAND	a)	--	0.042	--	0.632	--	0.156	0.322	0.529	0.021	0.067	0.389	1.380	1.769
	b)	--	0.013	--	1.035	--	0.103	0.322	0.380 ³⁾	0.021	0.023	0.345	1.552	1.897
U.K.	a)	2.738	--	3.988	1.916	1.226	--	0.053	2.135	--	--	10.140	1.916	12.056
	b)	2.997	--	5.217	2.037	1.240	--	0.053	3.798	--	--	13.305	2.037	15.342
U.S.A.	c)	40.410	-2.110	23.260	36.830	16.250	4.610	3.977	28.523	--	0.313	109.733	39.330	149.063
"GROUP OF 13"	a)	50.261	8.712	32.033	76.796	25.568	12.457	12.712	57.720	0.124	9.912	187.677	98.618	286.295
	b)	50.851	9.589	33.262	80.417	25.389	12.839	12.712	61.597	0.124	9.854	193.285	103.349	296.634

a) Low Case; b) High Case; c) Base Case

1) The national demand and supply projections for 1985 and 2000 have been made by the IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.

2) Net import equals import minus export minus bunkering.

3) All nuclear is treated as "domestic" except for Switzerland which classifies nuclear as "imported".

TABLE 9: TOTAL NET IMPORT OF ENERGY AND NET OIL IMPORT BY NATION

(NOTE: The national demand and supply projections for 1985 and 2000 have been made by IEA Energy Systems Analysis Groups at BNL and KFA. The national projections were made in different ways and thus are not directly comparable.

(10^{18} Joules)

NATION	TOTAL NET IMPORT			NET OIL IMPORT		
	1974 ^{d)}	1985	2000	1974 ^{d)}	1985	2000
BELGIUM a) b)	1.731	2.058	2.717	1.085	1.280	1.732
		2.371	3.598		1.482	2.297
CANADA c)	-1.469	0.754	2.004	-0.506	1.911	2.004
DENMARK a) b)	0.782	0.725	1.050	0.688	0.560	0.801
		0.986	1.679		0.862	1.472
GERMANY a) b)	5.520	7.779	9.019	5.414	6.096	7.395
		8.289	10.363		6.508	8.640
IRELAND c)	0.264	0.335	0.568	0.239	0.314	0.452
JAPAN c)	13.254	22.256	34.554	10.976	17.028	19.943
NETHERLANDS a) b)	-0.378	0.167	3.413	1.084	1.699	2.194
		1.056	4.998		2.393	2.810
NORWAY c)	0.237	-2.309	-2.795	0.244	-1.373	-1.373
SPAIN c)	1.836	2.259	3.871	1.714	1.986	2.870
SWEDEN c)	1.212	1.491	1.591	1.110	1.345	1.400
SWITZERLAND a) b)	0.674	0.912	1.380	0.584	0.584	0.632
		0.922	1.552		0.680	1.035
UNITED KINGDOM a) b)	4.811	-0.529	1.916	4.777	-0.529	1.916
		-2.117	2.037		-2.117	2.037
UNITED STATES c)	12.133	28.200	39.330	12.825	22.660	36.830
TOTAL GROUP OF "13" a) b)	40.607	64.098	98.618	40.234	53.561	76.796
		64.493	103.350		53.679	80.417

- a) "Low" case
b) "High" case
c) "Base" case
d) Actual

TABLE 10: NET ELECTRICITY GENERATION¹⁾
(10¹⁸ Joules)

COUNTRY		NET ELECTRICITY GENERATION FROM FOSSIL FUELS			NET ELECTRICITY GENERATION FROM NON-FOSSIL SOURCES			TOTAL NET ELECTRICITY GENERATION		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	0.141	0.133	0.094	0.003	0.073	0.271	0.144	0.206	0.365
	b)		0.157	0.116		0.096	0.381		0.253	0.497
CANADA	c)	0.199	0.346	0.530	0.806	1.221	2.330	1.005	1.567	2.860
DENMARK	a)	0.063	0.103	0.159	--	--	--	0.063	0.103	0.159
	b)		0.108	0.190		--	--		0.108	0.190
GERMANY	a)	0.940	0.982	1.066	0.106	0.776	2.651	1.046	1.258	3.717
	b)		1.015	1.061		0.870	3.307		1.885	4.368
IRELAND	c)	0.025	0.047	0.070	0.003	0.003	0.040	0.028	0.050	0.110
JAPAN	c)	1.078	1.450	1.927	0.376	1.434	4.520	1.454	2.884	6.447
NETHERLANDS	a)	0.179	0.210	0.214	0.011	0.034	0.129	0.190	0.244	0.343
	b)		0.266	0.300		0.034	0.188		0.300	0.488
NORWAY	c)	0.001	--	0.019	0.276	0.353	0.539	0.276	0.353	0.557
SPAIN	c)	0.143	0.190	0.184	0.131	0.543	2.115	0.274	0.733	2.299
SWEDEN	c)	0.054	0.068	0.110	0.211	0.444	0.695	0.265	0.512	0.805
SWITZERLAND	a)	0.020	0.008	0.013	0.108	0.184	0.264	0.128	0.192	0.277
	b)		0.007	0.007		0.169	0.229		0.176	0.236
U.K.	a)	0.726	0.863	0.882	0.128	0.228	0.770	0.854	1.091	1.652
	b)		1.035	0.912		0.241	1.357		1.276	2.269
U.S.A.	c)	5.216	7.150	8.620	1.498	4.370	11.550	6.714	11.520	20.170
TOTAL GROUP OF "13"	a)	8.785	11.550	13.888	3.657	9.663	25.874	12.442	21.213	39.761
	b)		11.839	14.052		9.778	27.251		21.617	41.296

- a) "Low" Case
b) "High" Case
c) "Base" Case

1) Before transmission and distribution losses.

TABLE 11: TOTAL FINAL CONSUMPTION, FINAL ENERGY CONSUMPTION AND NON-ENERGY USES BY NATION
(10¹⁸ Joules)

COUNTRY		1974			1985			2000		
		Final (Total)	Final (Excluding Non-Energy)	Non- Energy	Final (Total)	Final (Excluding Non-Energy)	Non- Energy	Final (Total)	Final (Excluding Non-Energy)	Non- Energy
BELGIUM	a)				1.954	1.668	0.286	2.802	2.208	0.594
	b)	1.503	1.353	0.150	2.223	1.867	0.356	3.652	2.796	0.856
CANADA	c)	5.836	5.486	0.350	8.215	7.280	0.935	12.552	11.268	1.284
DENMARK	a)				0.662	0.649	0.014	0.996	0.974	0.022
	b)	0.558	0.549	0.009	0.783	0.769	0.014	1.327	1.304	0.023
GERMANY	a)				10.374	9.537	0.837	13.475	12.442	1.033
	b)	8.006	7.138	0.868	11.037	10.137	0.900	15.625	14.447	1.178
IRELAND	c)	0.245	0.234	0.011	0.335	0.308	0.027	0.534	0.492	0.042
JAPAN	c)	11.259	9.604	1.655	20.966	18.079	2.887	35.265	30.938	4.327
NETHERLANDS	a)				2.863	2.418	0.445	3.758	3.234	0.524
	b)	2.172	1.863	0.309	3.637	2.878	0.759	5.231	4.345	0.886
NORWAY	c)	0.560	0.536	0.024	0.859	0.808	0.051	1.376	1.269	0.107
SPAIN	c)	1.740	1.620	0.120	3.164	2.909	0.255	6.659	6.179	0.480
SWEDEN	c)	1.361	1.305	0.056	1.832	1.745	0.087	2.179	2.061	0.118
SWITZERLAND	a)				0.829	0.829	--	1.104	1.104	--
	b)	0.676	0.650	0.026	0.865	0.865	--	1.322	1.322	--
U.K.	a)				6.969	6.199	0.770	8.124	7.019	1.105
	b)	6.685	6.157	0.528	7.627	6.740	0.887	10.114	8.481	1.633
U.S.A.	c)	56.990	52.369	4.621	76.300	67.970	8.330	99.440	88.190	11.250
TOTAL GROUP OF "13"	a)				135.323	120.399	14.924	188.264	167.378	20.886
	b)	97.591	88.864	8.727	137.843	122.355	15.488	195.276	172.092	22.184

a) "Low" Case
b) "High" Case
c) "Base" Case

TABLE 12: FINAL ENERGY CONSUMPTION BY DEMAND SECTOR AND NATION¹⁾

(10¹⁸Joules)

COUNTRY	INDUSTRY			RESIDENTIAL & COMMERCIAL			TRANSPORTATION		
	1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	0.878	1.291		0.544	0.656		0.246	0.261
	b)	0.659	0.967	0.498	0.601	0.832	0.196	0.299	0.340
CANADA	c)	1.957	2.228	2.130	2.734	3.736	1.399	2.318	3.901
DENMARK	a)	-0.199	0.280		0.281	0.429		0.169	0.265
	b)	0.123	0.218	0.294	0.356	0.601	0.132	0.195	0.337
GERMANY	a)	3.820	4.984		3.927	5.251		1.790	2.207
	b)	2.803	4.108	3.052	4.156	5.901	1.283	1.873	2.432
IRELAND	c)	0.082	0.115	0.091	0.112	0.182	0.061	0.081	0.127
JAPAN	c)	5.256	9.990	2.488	4.926	9.359	1.860	3.163	5.930
NETHERLANDS	a)	0.816	1.240		1.236	1.592		0.366	0.402
	b)	0.756	1.223	0.850	1.289	1.654	0.257	0.366	0.450
NORWAY	c)	0.251	0.392	0.179	0.214	0.304	0.106	0.202	0.361
SPAIN	c)	0.781	1.597	0.358	0.606	1.416	0.480	0.707	1.577
SWEDEN	c)	0.598	0.838	0.499	0.609	0.590	0.208	0.298	0.370
SWITZERLAND	a)	0.203	0.302		0.422	0.551		0.203	0.251
	b)	0.168	0.206	0.314	0.449	0.694	0.169	0.210	0.293
U.K.	a)	2.382	2.693		2.171	2.469		1.646	1.857
	b)	2.482	2.627	2.387	2.385	3.076	1.288	1.728	1.930
U.S.A.	c)	16.495	22.460	17.054	21.850	25.500	18.820	23.660	30.020
TOTAL GROUP OF "13"	a)	45.918	67.815		39.632	52.055		34.849	47.529
	b)	32.411	46.969	30.194	40.287	53.845	26.259	35.100	48.068

- a) "Low" Case
- b) "High" Case
- c) "Base" Case

1) Excluding non-energy uses.

TABLE 13: INDUSTRY FUEL MIX BY NATION¹⁾
(PERCENT)

COUNTRY		ELECTRICITY			FOSSIL FUELS			OTHER ²⁾		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	10.5	10.8	12.3	87.8	88.0	87.0	1.7	1.2	0.7
	b)		12.0	13.0		87.0	86.5		1.0	0.5
CANADA	c)	17.6	21.0	26.2	82.4	79.0	74.8	--	--	--
DENMARK	a)	11.4	13.2	13.6	84.5	85.0	84.6	4.1	1.8	1.8
	b)		12.1	12.7		86.2	85.7		1.7	1.6
GERMANY	a)	13.5	18.6	26.7	85.4	78.2	66.9	1.1	3.2	6.4
	b)		18.6	26.7		78.2	66.9		3.2	6.4
IRELAND	c)	9.0	14.1	19.6	91.0	85.9	80.4	--	--	--
JAPAN	c)	11.4	12.6	16.2	88.6	87.4	83.8	--	--	--
NETHERLANDS	a)	8.3	7.2	7.9	90.9	92.1	91.6	0.8	0.7	0.5
	b)		7.0	8.5		92.6	91.2		0.4	0.3
NORWAY	c)	47.7	40.8	42.2	52.3	59.2	57.8	--	--	--
SPAIN	c)	15.8	19.7	31.9	84.2	80.3	68.1	--	--	--
SWEDEN	c)	21.6	26.1	30.5	56.3	58.3	57.6	22.2	15.6	11.9
SWITZERLAND	a)	20.8	26.8	23.6	78.7	71.7	70.7	0.5	1.8	6.7
	b)		23.5	18.8		75.7	79.8		1.0	1.4
UNITED KINGDOM	a)	8.8	12.9	14.2	91.2	87.1	85.8	--	--	--
	b)		13.2	13.7		86.8	86.3		--	--
UNITED STATES	c)	11.8	12.3	17.0	89.3	87.7	83.0	--	--	--

a) Low Case b) High Case c) Base Case

1) Distribution of Total Final Consumption (including non-energy uses) by energy form.

2) District Heating included.

TABLE 14: RESIDENTIAL AND COMMERCIAL FUEL MIX BY NATION¹⁾
(PERCENT)

COUNTRY		ELECTRICITY			FOSSIL FUELS			OTHER		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	8.6	10.9	14.6	91.1	88.8	85.1	0.3	0.3	0.3
	b)		10.6	14.4		89.2	85.4		0.2	0.2
CANADA	c)	21.7	28.6	38.5	78.3	71.4	61.5	--	--	--
DENMARK	a)	13.5	22.1	23.4	67.4	53.5	53.8	19.1	24.4	22.8
	b)		18.4	19.3		64.0	64.9		17.6	15.8
GERMANY	a)	13.2	17.2	30.7	83.4	74.8	49.2	3.4	8.0	20.1
	b)		17.3	31.0		74.6	48.5		8.1	20.5
IRELAND	c)	15.8	19.6	26.3	84.2	80.4	73.7	--	--	--
JAPAN	c)	17.7	17.6	25.3	82.3	82.4	68.8	--	--	5.9
NETHERLANDS	a)	9.3	10.5	10.9	90.0	89.0	88.7	0.7	0.5	0.4
	b)		10.4	11.0		89.1	88.6		0.5	0.4
NORWAY	c)	51.7	59.7	61.9	48.3	40.3	37.1	--	--	1.0
SPAIN	c)	23.8	39.1	53.7	76.2	60.9	45.7	--	--	0.6
SWEDEN	c)	20.3	35.3	57.6	69.1	57.3	14.4	10.6	21.5	28.0
SWITZERLAND	a)	18.3	22.0	26.9	77.0	73.6	59.8	4.7	4.4	13.3
	b)		19.9	17.8		78.2	79.5		1.9	2.7
U.K.	a)	20.6	26.1	38.6	79.4	73.9	61.4	--	--	--
	b)		28.4	44.2		71.6	55.8		--	--
UNITED STATES	c)	21.3	29.7	41.6	78.7	70.3	58.4	--	--	--

a) Low Case B) High Case c) Base Case

1) Distribution of Final Energy Consumption by energy form.

TABLE 15: TRANSPORTATION FUEL MIX BY NATION¹⁾
(PERCENT)

COUNTRY		ELECTRICITY			FOSSIL FUELS			OTHER		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	1.6	1.6	2.7	98.4	98.4	97.3	--	--	--
	b)		2.3	2.9		97.7	97.7		--	--
CANADA	c)	--	--	--	100.0	100.0	100.0	--	--	--
DENMARK	a)	0.3	0.4	0.4	99.7	99.6	99.6	--	--	--
	b)		0.3	0.3		99.7	99.7		--	--
GERMANY	a)	2.6	4.5	5.7	97.4	95.5	94.3	--	--	--
	b)		4.5	5.9		95.5	94.1		--	--
IRELAND	c)	--	--	--	100.0	100.0	100.0	--	--	--
JAPAN	c)	2.6	2.4	2.0	97.4	97.6	98.0	--	--	--
NETHERLANDS	a)	1.2	1.3	1.3	98.8	98.7	98.7	--	--	--
	b)		1.3	1.2		98.7	98.8		--	--
NORWAY	c)	1.6	0.9	0.6	98.4	99.1	99.4	--	--	--
SPAIN	c)	1.0	2.3	3.3	99.0	97.7	96.7	--	--	--
SWEDEN	c)	3.7	3.6	4.9	96.3	96.4	95.1	--	--	--
SWITZERLAND	a)	4.3	4.1	5.5	95.7	95.9	93.7	--	--	--
	b)		3.6	2.9		96.4	97.1		--	--
UNITED KINGDOM	a)	0.8	0.8	0.7	99.2	99.2	99.3	--	--	--
	b)		0.7	0.7		99.3	99.3		--	--
UNITED STATES	c)	0.1	0.1	0.1	99.9	99.9	99.9	--	--	--

a) Low Case b) High Case c) Base Case

1) Distribution of Final Energy Consumption by energy form.

TABLE 16
PRIMARY ENERGY CONSUMPTION, TOTAL FINAL CONSUMPTION, AND GENERATION OF ELECTRICITY PER CAPITA BY NATION
(10⁹ JOULES PER CAPITA)

COUNTRY		CONSUMPTION OF PRIMARY ENERGY PER CAPITA			TOTAL FINAL CONSUMPTION ¹⁾ PER CAPITA			GENERATION OF ELECTRICITY PER CAPITA		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	194.08	250.61	370.92	153.52	199.39	285.92	14.71	21.02	37.24
	b)		288.78	490.41		226.84	372.65		25.82	50.71
CANADA	c)	375.56	466.15	602.39	259.38	315.96	406.21	44.67	60.27	92.56
DENMARK	a)	145.15	167.88	239.06	109.64	127.50	187.92	12.48	19.81	30.00
	b)		196.35	318.68		150.58	250.38		20.77	35.85
GERMANY	a)	172.76	242.42	370.60	129.02	174.06	230.34	16.86	29.50	63.54
	b)		258.31	431.66		185.18	267.09		31.63	74.67
IRELAND	c)	102.27	124.29	172.62	79.29	95.19	127.14	9.06	14.29	26.19
JAPAN	c)	134.62	226.34	412.65	102.31	170.04	260.84	13.21	23.39	47.68
NETHERLANDS	a)	196.96	244.82	315.56	160.89	205.97	260.97	14.07	17.55	23.82
	b)		309.64	437.78		261.65	363.26		21.58	33.89
NORWAY	c)	201.50	286.43	443.18	140.35	204.52	312.73	69.17	84.05	126.59
SPAIN	c)	74.84	128.26	258.47	49.53	81.13	147.98	7.80	18.79	51.09
SWEDEN	c)	233.41	338.31	420.12	165.98	200.72	256.35	32.32	61.69	94.71
SWITZERLAND	a)	123.75	191.23	268.03	105.63	127.54	167.27	20.00	29.54	41.97
	b)		191.23	287.42		133.08	200.30		27.08	35.76
UNITED KINGDOM	a)	169.39	174.67	209.67	119.25	122.91	141.29	15.23	19.24	28.73
	b)		194.55	266.82		134.51	175.90		22.50	39.46
UNITED STATES	c)	360.63	451.32	565.06	268.96	325.37	376.95	31.69	49.13	76.46
WEIGHTED AVERAGE ²⁾	a)	240.35	317.76	444.49	178.18	229.16	292.28	22.72	35.92	61.73
	b)		323.68	460.54		233.43	303.18		36.61	64.12

a) Low Case

b) High Case

c) Base Case

1) Includes non-energy uses.

2) Weighted by Population.

TABLE 17: FINAL ENERGY CONSUMPTION PER CAPITA BY DEMAND SECTORS BY NATION¹⁾
(10⁹ JOULES/CAPITA)

COUNTRY		INDUSTRY			RESIDENTIAL & COMMERCIAL			TRANSPORTATION		
		1974	1985	2000	1974	1985	2000	1974	1985	2000
BELGIUM	a)	67.4	89.7	131.7	50.8	55.5	66.9	20.0	25.1	26.6
	b)		98.7	165.7		61.4	84.9		30.5	34.7
CANADA	c)	87.0	86.0	117.4	94.7	105.6	120.9	62.2	89.5	126.2
DENMARK	a)	24.3	38.2	52.7	59.8	54.0	80.9	24.6	32.5	50.1
	b)		41.9	69.2		68.5	113.4		37.6	63.6
GERMANY	a)	45.2	64.1	85.2	49.2	65.9	89.8	20.7	30.0	37.7
	b)		68.9	104.5		69.7	100.9		31.4	41.6
IRELAND	c)	26.4	32.9	43.3	29.3	31.5	42.9	19.8	22.9	29.9
JAPAN	c)	47.8	81.0	115.8	22.6	39.9	69.2	16.9	25.7	43.9
NETHERLANDS	a)	56.0	58.7	86.1	63.0	99.0	110.6	19.1	26.4	27.9
	b)		88.0	155.6		92.8	114.9		26.4	31.2
NORWAY	c)	62.8	94.2	138.1	44.9	51.3	69.6	26.7	48.6	82.7
SPAIN	c)	22.2	40.9	70.8	10.2	15.5	31.5	13.7	18.1	35.0
SWEDEN	c)	73.0	101.0	129.5	60.8	73.4	69.4	25.4	35.9	43.5
SWITZERLAND	a)	26.3	31.7	47.2	48.3	64.9	84.8	25.6	30.8	38.0
	b)		32.2	52.3		69.1	106.8		31.8	43.4
U.K.	a)	44.3	42.0	46.8	42.6	38.3	42.9	23.0	29.0	32.3
	b)		46.3	60.4		42.1	53.5		30.5	33.6
U.S.A.	c)	77.8	95.8	123.8	80.5	93.2	96.7	88.8	100.9	113.8
WEIGHTED AVERAGE ²⁾	a)	59.2	77.8	105.3	55.1	67.14	80.83	47.9	59.1	73.8
	b)		79.5	110.5		68.24	83.63		59.5	74.6

- a) "Low" Case
b) "High" Case
c) "Base" Case

- 1) Excluding non-energy uses
2) Weighted by population

TABLE 18: OIL AND GAS CONSUMPTION PER CAPITA BY NATION
(10⁹ JOULES/CAPITA)

COUNTRY	DIRECT USE ¹⁾ OF OIL AND GAS			OIL AND GAS USE FOR ELECTRICITY GENERATION		
	1974	1985	2000	1974	1985	2000
BELGIUM a) b)	110	151	229	30	28	22
		177	311		30	25
CANADA c)	229	275	339	11	12	11
DENMARK 2) a) b)	101	106	147	25	28	41
		136	219		36	59
GERMANY a) b)	99	131	153	12	18	20
		139	176		19	20
IRELAND c)	59	73	95	17	27	12
JAPAN c)	79	130	178	24	28	15
NETHERLANDS a) b)	151	192	216	35	30	18
		243	256		38	25
NORWAY c)	80	130	201	NEGL	NEGL	12
SPAIN c)	42	61	96	8	5	2
SWEDEN c)	112	130	125	11	12	20
SWITZERLAND a) b)	88	100	115	2	3	4
		111	170		3	3
UNITED KINGDOM a) b)	92	97	113	15	13	11
		105	136		15	11
UNITED STATES c)	238	275	272	35	27	23
WEIGHTED AVERAGE 3) a) b)	151	188	210	24	22	18
		191	218		23	18

a) Low case b) High case c) Base case

1) Direct Use includes losses in refineries.

2) Includes coupled heat/power production.

3) Weighted by population.

3. NEW AND CONSERVATION TECHNOLOGIES

3.1 National Selection of Technologies for Assessment

The technologies listed in the 5 categories below were identified in February 1976 by the IEA Steering Group on Systems Analysis as being of likely interest to the IEA member nations:

I.

Breeder Reactors
Secondary and Tertiary Recovery of Oil
Conservation¹⁰⁾

II.

Solar Heating and Cooling
Improved Utilization of Coal
Shale Oils and Tar Sands
Hydrogen Production & Utilization, Electrolysis
High Temperature Reactor - Power and Process Heat
Solar Thermal Electric (USA only)
Wave (Great Britain only)

III.

Coal Conversion
Geothermal (Italy, New Zealand)

IV.

Solar Thermal Electric (Outside USA)
Fusion
Photo - Voltaic
Tidal
Wind

¹⁰⁾ Assumed to mean conservation technologies requiring R&D, as opposed to conservation realized through policy actions and price increases.

V.

Geothermal (other than Italy and New Zealand)
Biomass
Energy Storage
Ocean Thermal Gradients

These selections were grouped into the five categories with those likely to be of most interest in Group I and those of least interest in V, with respect to the following criteria:

- a) the theoretical and physical potential of providing a useful energy resource,
- b) the estimated time lag until commercialization,
- c) the quantity of energy which would be yielded under commercial conditions, and by implication,
- d) the degree of domestic availability of the new resource.

These technologies all require additional R&D effort before they can assume a useful role in the energy systems and successfully compete with existing technologies. Although some of these new technologies have been extensively characterized from the engineering design point of view, a complete description of the economic, environmental, and other features of commercial units is often lacking. Quantitative descriptions of such characteristics are essential to the evaluation of the benefits to be derived from and costs to be incurred by new energy systems. Technologies relating to energy conservation (improved efficiency in energy usage, the technological consequences of government conservation policies, etc.) also require extensive quantitative characterization for systems

analysis studies. Energy conservation technologies present a particularly difficult problem in characterization since they relate to an almost unlimited number of producing and consuming devices and are highly specific to those and only those devices.

For the purposes of the Phase I Systems Analysis Program, the participating nations were invited to select six of the technologies included in the above list for first round assessments. This selection did not necessarily imply that the chosen six were the most likely to yield the largest benefits. In some cases, the most important technologies were omitted because they had been previously analyzed in great detail. Often the choices expressed the desire to obtain a better understanding of technologies less thoroughly investigated. Omission of any one technology from the choice of six does not imply a lack of interest by the nation concerned.

A summary of the six technologies selected by each participating nation is given in Table 19 (p. 30). These technologies were to be characterized in terms of technological, economic, implementation, and environmental factors. The following sections summarize the efforts which have been completed so far.

It must be emphasized that these characterizations are of a very preliminary nature. Further work and a greater depth of analysis will be required.

3.2 The Characterization of New Technologies

The overall objective of the IEA systems analysis program is to provide an analytical basis for the assessment of energy technologies in support of the formulation of a strategy for energy research and development programs.

In order to assess any new technology, it is first necessary to decide upon some common unit of measure of its quality. If such qualities can be assessed, it becomes possible to rank the technologies in order of preference and to make choices between alternatives as required.

It is well known that uncertainty is an unavoidable aspect of R&D projects. In fact, one of the primary reasons for undertaking R&D projects is to reduce uncertainty: uncertainty in technical feasibility, engineering design, manufacturing methods, marketing strategy, etc. It is also true that estimates of the future become more uncertain as the time horizon recedes.

Any assessment of new or conservation technologies should, therefore, take account of this uncertainty in a logical and consistent way. There is also a need for the analyst to convey the magnitude of these uncertainties to the decision maker so that the latter can apply his own preferences with regard to his propensity for risk-taking in the evaluation of projects.

In order to facilitate comparison between various existing and new technologies, a "Standard Table of Characteristics of Technological Processes" was produced in the form of a questionnaire (Figures 1-3, pp. 31-33). This questionnaire consists of four basic sections. The first of these requires data of a purely technological nature, e.g., primary fuel input and primary efficiency. The second section requires cost and lifetime data, future and past R&D costs being solicited, as well as capital and operating costs. The third section asks for estimates of time to commercialization and estimates of implementation levels at five-yearly intervals from 1975 until 2000. Of course, the rate of implementation

TABLE 19

NATIONAL SELECTIONS OF NEW AND CONSERVATION TECHNOLOGIES

As required by the IEA Work Plan, each participating national representative selected six technologies which were considered of prime importance for the first round assessment of this particular study. Omission of any technology should not be taken to indicate a lack of interest by the nation concerned.

[illegible]

Figure 1

SEE NOTE	STANDARD TABLE OF CHARACTERISTICS OF TECHNOLOGICAL PROCESSES					
1	NAME:	LOCATION:			DATE:	
2	TECHNOLOGY:	ACTIVITY:				
3	COUNTRY:	UNIT OF MEASURE:				
4		Answer in the Dimension Below	National or Mean	Likely to Exceed	Unlikely to Exceed	Quality and/or Comment
5	<u>Technological Data</u> (Energy Requirements per unit of measure)					
6	Primary Fuel	Joules x 10 ¹⁵				
7	Secondary (Ancillary Fuel)-	Joules x 10 ¹⁵				
8	- Other	Joules x 10 ¹⁵				
9	Plant Availability Factor	Percentage				
10	Net Energy Output	Joules x 10 ¹⁵				
11	Primary Efficiency	Percentage				
12	<u>Cost</u>					
13	Capital Cost per Unit of Measure	\$ x 10 ³				
14	Operating Cost per 10 ¹⁵ Joules output	\$ x 10 ³				
15	Future R&D Cost	\$ x 10 ³				
16	Past R&D Cost	\$ x 10 ³				
17	Lifetime	Years				
18						
19	<u>Implementation</u>					
20	Time to Commercialization	A Given Year				
21	Implementation Level by					
	1975					
	1980					
	1985					
	1990					
	1995					
	2000					

Figure 2

Page 2 of 3

SEE
NOTE

		Answer in the Dimension Below	National or Mean	Likely to Exceed	Unlikely to Exceed	Quality and/or Comment
22	<u>Environment</u>					
23	<u>Water:</u>					
	Acids	Tons per 10 ¹⁵ Joules				
	Bases	"				
	PO ₄	"				
	NO ₃	"				
	Dissolved Solids	"				
	Suspended Solids	"				
	BOD	"				
	COD	"				
	Thermal	Joules per 10 ¹⁵ Joules				
	Consumptive Water Use	Cubic Kms per 10 ¹⁵ Joules				
	Non-consumptive Water Use	"				
24	<u>Air:</u>					
	Macro particulates	Tons per 10 ¹⁵ Joules				
	Micro particulates	"				
	NO _x	"				
	SO _x	"				
	HC	"				
	CO	"				
	CO ₂	"				
	Trace metals	"				
	Aldehydes	"				
	Solid Waste	"				
	Thermal	Joules per 10 ¹⁵ Joules				
	Noise	On a scale 1 - 5				

Figure 3

SEE
NOTE

		Answer in the Dimension Below	National or Mean	Likely to Exceed	Unlikely to Exceed	Quality and/or Comment
25	<u>Land:</u> Land Use Visual Pollution Seismic Effects	Km Sq P. A. On a scale 1 - 5 On a scale 1 - 5				
26	<u>Radiation:</u> Tritium Krypton-85 Solid High-Level Waste Population Exposure	Curies Curies Curies Man-REM				
27	<u>Health:</u> Occupational Deaths Occupational Injuries Occupational Man Days Lost Potential Large-Scale Disaster	Deaths P.A. Injuries P.A. Days Lost P.A. Prob. of Occurrence				
28	<u>Controls:</u> Impacts of Controls on Cost Impacts of Controls on Efficiency	On a scale 1 - 5 On a scale 1 - 5				

of a technology is a function of many social, political, economic, environmental, and technological factors, and, therefore, values which are an aggregate of these factors are sought. The final, and largest, section is devoted to various environmental factors (not presented in this report).

For each data element, four questions are asked:

The first question asks for either an official national figure or a best estimate for the data element, whereas the next two questions ask for estimates which have respectively a 90% and 10% chance of being exceeded in reality. Finally, it is requested that the quality of the data be expressed by one of five "numerical quality indicators" which are defined as follows:

1. very good, highest confidence, error probably 10 percent, data well accepted and verified;
2. good, reputable and accepted, error probably 25 percent;
3. fair, error probably 50 percent, validity may be uncertain because of method of combining or applying data;
4. poor, low confidence in data, error probably 100 percent, validity questionable;
5. very poor, validity of data unknown, error probably within or around an order of magnitude.

Answers to these questions can then be used, if desired, in a probabilistic data analysis for that group of countries which have chosen the particular

technology in question. The details of this analysis are described in a separate report.¹¹⁾

Because of the short time period available to the BNL and KFA working groups, it was decided that the groups would concentrate initially on collecting the technological, cost, and implementation estimates data. Therefore, environmental data have not been included in this report, although coordination has been initiated between the working groups and the OECD environmental group, and environmental impacts will be assessed in the Phase II program.

3.3 Perturbation Analysis

A preliminary assessment of the benefits to be derived from a new technology can be obtained by conducting a perturbation analysis on the Reference Energy System (RES). The procedure is to introduce the technology into the RES diagram at the appropriate point and at the estimated level of implementation (obtained from the characterization tables (Fig. 1)). Obviously, the uncertainty in the result is directly related to the uncertainty in the implementation estimate. These uncertainties are expressed by the range between low and high values.

The analyst must allocate the market share of the new technology by subjective judgment. For example, if a given level of solar residential space heat is introduced, the analyst must decide what fraction of this displaces each of the other means of space heating. In the Phase II program, this subjective allocation procedure will be replaced by cost analysis and an examination of other driving

11) Preliminary Technology Appendix, Characterization of Energy R&D Technologies, revised Jan. 31, 1977. (Available upon request from either of the project directors.)

factors such as policy, regulation, incentive, etc., which influence market penetration.

In many cases, the perturbations would allow a wide variety of inter-fuel substitutions. In choosing between the many alternatives, the guiding philosophy was that the preferred substitutions at the primary resource side would reduce the requirements for crude oil and natural gas.

The final results of the single technology perturbations were expressed in terms of direct oil and gas savings, indirect oil and gas savings in the electrical generation sector, total oil and gas savings, and total primary energy savings.

For most countries, each of the six selected technologies was assessed for 1985 and 2000 using low, high, and mean implementation estimates. Often the selected technology had no impact as early as 1985. Often the results proved to be extremely sensitive to the baseline projections themselves as well as to the decisions of the analyst on allocations. In such cases, greater depth of analysis will be needed in the future.

3.4 International and Intertechnology Comparisons

The Steering Group work plan specifies that the benefits of new technologies "will be quantified in terms of the savings of scarce resources", and particularly "replacement of oil and gas". The outcome of the perturbation analysis for each country and each technology has been expressed in these terms (data are presented in Section 4.1).

However, this approach does not reveal the full story, because the interdependency of supply within the Group is neglected, and the savings anticipated

for the larger countries overwhelm the savings of the smaller nations. Thus, the IEA decision-makers receive little guidance on the merit of various strategies relevant to the smaller countries.

If we are to make direct comparisons of the impact of a new technology upon different nations of various sizes, and to compare the impact of different technologies, it is necessary to have a common unit of measure. While such units can be many and varied, our preliminary work has been limited to the following line of development.

Oil Equivalence

The OECD energy statistics have utilized a common factor of measurement in the form of tons of oil equivalent (t.o.e.) "since it is easily understood and quantities of oil are an important element in policy decisions". However, as oil is a diminishing resource and as this report is primarily concerned with the effects of implementing alternative technologies many years in the future, it is appropriate to make assessments in terms of absolute units of energy, i.e., joules. The energy contributed to or saved within the system by the introduction of a new or conservation technology will be expressed in joules.

Country Independent Evaluation

The saving of a quantity of energy in country A, by the use of some specified technology, cannot be compared directly with a similar activity in country B, because of their difference in size, indigenous resources, population, GDP, etc.

In order to make international comparisons, the data have been presented in three ways:

1. Oil and gas savings per capita.
2. Oil and gas savings as a percentage of anticipated oil and gas requirements for each country.
3. Oil and gas savings as a percentage of total oil and gas requirements for the Group.

Dollar Equivalence

It is often difficult to visualize the benefits derived from new technologies from data expressed in energy units. Such quantities can be roughly converted to monetary terms by assuming some nominal price for the oil and gas saved. An appropriate conversion factor at the present time is $\$2 \times 10^9$ per 10^{18} joules, which is equivalent to an oil price of $\$12.20/\text{bbl}$. In the analysis, we have assumed that this price remains constant in the future. This conversion factor is arbitrary and is not intended to represent a realistic price of fuel in any particular location, nor to reflect possible future trends in fuel prices.

Discounting the Benefits

The IEA work plan states that the analytical capability should provide the magnitude and timing of contributions to energy supplies for new and developing energy technologies.

If we are to attempt to provide a single common unit of measurement for comparison purposes which includes a time element, then discounting is one method of achieving this end. Implicit in the use of discounting is the well observed trait of society that it is prepared to pay a high premium for a time advantage. By this, we mean that the dollar value of

energy saving now (in terms of joules, Btu's, etc.) is worth more to the policy maker than the same energy savings made at some future date.

The benefits have been evaluated using three different discount rates, 0%, 5%, and 10%. The 0% case, of course, corresponds to a non-discounted benefit.

Shortcomings of the "Discounted Benefit" Approach

At this stage of development, this approach has some obvious shortcomings which must be kept in mind:

- a) The analysis concerns only the benefits side of the cost/benefit relation. It is not a cost/benefit analysis as it does not consider the direct costs nor externalities associated with the technology.
- b) The appropriate discount rate might differ between countries and be a function of time.
- c) Long term development technologies will probably fare badly in any comparative analysis involving discounting because of the longer lead times.
- d) No account is taken of environmental effects.

Alternative Indicators

Because of the above shortcomings, we have presented the technological assessments in terms of more than one indicator. The data presented in Section 4.1 use several approaches.

- a) Total savings in oil and gas,

- b) Oil and gas savings per capita,
- c) Oil and gas savings as a percentage of oil and gas requirements of each country,
- d) Oil and gas savings as a percentage of oil and gas requirements of the Group.
- e) Discounted benefits in dollar equivalence.

but could result in savings of other primary fuels, e.g., coal. For this reason, the changes in the total non-renewable primary energy requirements have been calculated.

Assessment of LMFBR and HTR

In some cases, the introduction of breeder and high temperature reactors yields no apparent oil and gas savings. This comes about because, in some countries, LMFBR and HTR are introduced as substitutes for less fuel-efficient converter reactors. The principal benefits, according to the analyses of other groups,¹²⁾ are reduced requirements for uranium feedstock and lower costs for electricity and process heat (costs, of course, have not been evaluated in Phase I).

The savings in natural uranium feedstock and thorium requirements have been calculated which result from the implementation of LMFBR and HTR units that substitute for contemporary nuclear capacity.

Total Non-Renewable Primary Energy Savings

As observed in the preceding paragraph, the introduction of certain new technologies, in some cases, might yield no apparent oil and gas savings,

12) For example, see Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program, US Energy Research and Development Administration, December 1975, ERDA-1535.

4. ESTIMATED BENEFITS

4.1 Results of Perturbations

Oil and Gas Savings

A perturbation analysis was made for each country for each of the six selected technologies.¹³⁾ The details of how these perturbations were made can be found in the RES diagrams for the individual countries¹⁴⁾ or can be obtained from the national participants. The results are summarized in Tables 20 and 21 in terms of oil and gas savings per year for the mean values of the estimated implementation levels.

The oil and gas savings are derived with respect to the estimated implementation of the new technology and the reference projection used. As the national implementation estimates and projections were made in different ways by each country, caution must be exercised in making comparisons between countries.

It should be noted that the columns in the tables cannot be added vertically because some technologies are mutually exclusive. That is, if country A decides to develop technology X, it cannot necessarily at the same time develop technology Y, because of R&D budget constraints, resource or land use commitments, etc. However, totals across the rows are meaningful since the adoption of technology X by country A does not preclude adoption of the same technology by country B.

13) Some countries were unable to complete all six technologies because of difficulties in obtaining meaningful data.

14) See footnote (3), page 1.

As would be expected, the benefits are much larger in 2000 than in 1985. However, the collective magnitudes are small compared with the projected total energy requirements (Tables 5 and 6).

The data (mean values) for 2000 are summarized in three other ways: Oil and gas savings per year per capita (Table 22); Oil and gas savings as a percentage of the individual country's total oil and gas requirements (Table 23); and Oil and gas savings as a percentage of the "Group of 13" total oil and gas requirements (Table 24). Very preliminary rankings could be made from these tables on the basis of several different criteria; e.g., total oil and gas savings, savings per capita, and percentage savings. However, it must be emphasized that these results express only the benefit side of the cost/benefit equation. No analysis has been made of the direct and indirect costs associated with the implementation of each technology. In some cases, technologies which appear to offer the largest benefits could prove to be prohibitive in costs.

Following the procedure outlined in Section 3.4, the aggregated "discounted benefits" have been computed for 0%, 5%, and 10% discount rates and are presented in Table 25. These are shown both in absolute terms (dollar equivalence) and per capita. Table 25 gives data for the low and high implementation estimates. The magnitudes of the discounted benefits are not large whether viewed on an absolute or per capita basis.

Nuclear Savings

As noted earlier, the primary benefits from breeder and high temperature reactors, when substituting for other reactor types, appear in the form

of cost savings (not evaluated) and uranium savings. Thus, in examining the oil and gas savings (Tables 20-25), the breeder and high temperature reactors appear to offer little benefit. However, without reactor systems which provide better fuel-cycle efficiency than the contemporary light water reactors, the nuclear component included in the reference projections would eventually encounter uranium supply problems. Loss of the nuclear contribution, which provides 20% of the primary energy input in 2000, would measurably increase the problem of balancing supply/demand in the future.

Uranium savings and thorium requirements per year in 2000 obtained from the estimated implementation rates (mean values) are summarized in Table 26 for LMFBR and HTR. The values shown were based on equilibrium fuel cycles.

Total Non-Renewable Primary Energy Savings

As noted in Section 3.4, non-renewable primary energy savings other than oil and gas have resulted from certain perturbation analyses. Therefore, the changes in total non-renewable primary energy are given for each technology in Tables 27 and 28 for the mean values for 1985 and 2000 respectively.

4.2 Composite Strategies

In order to achieve a significant reduction in petroleum dependence, many technologies will have to be exploited simultaneously because no single new or conservation technology can provide enough energy to replace petroleum. Furthermore, most countries seek a more diversified base for their energy systems so that interruptions in one component will not have critical consequences. Thus, it is necessary to assess groups of technologies simultaneously to provide the policy maker with more realistic results.

The results of perturbation assessments using single technologies cannot be combined by simple addition, because in most circumstances several technologies compete for the same markets, R&D budgets, investments, and physical resources. Thus, in assessing groups of technologies, account must be taken of these interactions.

Different groupings of technologies are often called "strategies". In general, a strategy would include both developments produced by R&D and changes induced by policy decisions.

From among the 18 technologies studied in Phase I, many different combinations can be formed. Some groupings appear quite natural, e.g., the fossil technologies or the conservation technologies.

Of course groupings of most interest to one country might be of little interest to another. Several strategies of this nature have been considered by individual participants. Because of their preliminary nature and the limited number of technologies considered, the results have not been included in this report.

The investigation of a variety of alternative composite strategies will provide the R&D policy maker with a quantitative insight into the relative benefits, costs, and risks of failure associated with various R&D options. Cooperative R&D efforts spread among many nations can dilute the risk of technical failures that would otherwise be associated with a limited number of R&D options available to individual national programs. Competition between strategies for R&D funds, scientific manpower, physical resources, and economic costs preclude the pursuit of a large number of strategies simultaneously. The study of composite strategies will provide rankings according to several criteria, e.g., security of

supply, economic costs, total energy impact, relative environmental impacts, etc.

This subject will be the focal point of the next phase of the systems analysis program.

TABLE 20

1985: OIL AND GAS SAVINGS FROM IMPLEMENTATION OF NEW TECHNOLOGIES

(10¹⁵ JOULES)

(Phase I Estimates Based on Six Technologies Per Country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.	TOTAL
SOLAR HEATING	0	0.3	7	30	Negl.	59	0.23	Negl.	3.3	0.02	0.6	15	730	845
INSULATION	23		66	40	15		33.3	1.63			1.6	91	385	657
WASTE HEAT (Coupled Production)		3.2	23	20	1		-0.3	N.A.			0			47
FAST BREEDER	0			0		0			0		0	0	0	0
COAL CONVERSION	5.5	0		0		0	22.6					0		28
WIND CONVERSION		0.2	1.5		Negl.		1.3	0				5	47	53
H. T. R.				0		0			0		0			0
HEAT PUMPS			7		Negl.			Negl.			1.1			8
IRON/STEEL INDUSTRY		0					5.4			6.5				12
COAL COMBUSTION (FLUID. BED)										8		0	1147	1155
BIOMASS					Negl.					2.5				2
GEO THERMAL						150			0					150
WAVE ENERGY								0				1		1
TRANSPORT									92.6	10				103
ENHANCED OIL RECOVERY													2000	2000
SHALE OIL										16				16
TAR SANDS 1)		234												234
CENTRALIZED SOLAR GENERATION						0								0

1) Includes enhanced oil recovery.

TABLE 21

2000: OIL AND GAS SAVINGS FROM IMPLEMENTATION OF NEW TECHNOLOGIES

(10¹⁵ JOULES)(Phase I Estimates Based on Six
Technologies Per Country)

	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.	TOTAL
SOLAR HEATING	11	7.9	28	125	12.1	551	46.4	1.15	18.8	4.5	7.2	51	5000	5864
INSULATION	65		95	100	58		75.4	24.0			7.3	263	466	1154
WASTE HEAT (Coupled Production)	N.A.	126.1	54	200	14		-0.9	N.A.			22.8			416
FAST BREEDER	85.2			0		210			0		0	702	3087	4084
COAL CONVERSION	114.7	182.5		200		1573	73.2					816		2965
WIND CONVERSION		19.4	9		11		15.7	1.34				95	1175	1326
H. T. R.	0			250		1602			0		58			1910
HEAT PUMPS			23		8.5			3.43			5.7			41
IRON/STEEL INDUSTRY		0					12.3			12				24
COAL COMBUSTION (FLUID. BED)						2359				85		248	6225	8917
BIOMASS					18					32				50
GEOTHERMAL						1897			16.2					1913
WAVE ENERGY								0.8				155		156
TRANSPORT									212.3	35				248
ENHANCED OIL RECOVERY													3450	3450
SHALE OIL										45				45
TAR SANDS ¹⁾		781												781
CENTRALIZED SOLAR GENERATION						630								630

TABLE 22

2000: OIL AND GAS SAVINGS PER CAPITA FROM IMPLEMENTATION OF NEW TECHNOLOGIES

(10⁹ JOULES/CAPITA)

(Phase I Estimates Based on Six Technologies Per Country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.
SOLAR HEATING	1.12	0.24	3.84	2.14	2.88	4.08	3.22	0.26	0.42	0.64	1.09	0.89	19.0
INSULATION	6.63		14.2	1.71	13.8		5.24	5.11			1.11	4.57	1.77
WASTE HEAT (Coupled Production)	N.A.	3.82	7.40	3.42	3.33		-0.06	N.A.			3.45		
FAST BREEDER	8.69			0		1.55			0		0	12.2	11.7
COAL CONVERSION	11.7	5.53		3.42		11.63	5.49					14.2	
WIND CONVERSION		0.59	0.16		2.62		1.09	0.30				1.65	4.45
H. T. R.	0			4.27		11.85			0		8.79		
HEAT PUMPS			3.15		2.02			0.76			0.86		
IRON/STEEL INDUSTRY		2.92					0.85			1.41			
COAL COMBUSTION (FLUID. BED)						17.45				10.0		4.31	23.6
BIOMASS					4.29					3.76			
GEO THERMAL						14.03			0.36				
WAVE ENERGY								0.18				2.70	
TRANSPORT									4.73	4.12			
ENHANCED OIL RECOVERY													13.1
SHALE OIL										5.29			
TAR SANDS		23.7											
CENTRALIZED SOLAR GENERATION						4.66							

TABLE 23

2000: OIL AND GAS SAVINGS FROM IMPLEMENTATION OF NEW TECHNOLOGIES
As A Percentage of the Individual Country's Total Oil and Gas Usage

(PERCENT)

(Phase I Estimates Based on Six Technologies Per Country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.
SOLAR HEATING	0.38	0.07	4.85	1.16	2.65	2.11	1.25	0.1	0.43	0.32	0.75	0.65	6.41
INSULATION	2.26		12.12	0.93	12.83		2.03	2.6			0.76	3.37	0.60
WASTE HEAT (Coupled Production)		1.16	4.36	1.86	3.10		3.2				2.37		
FAST BREEDER	2.96			0		0.80			0		0	8.99	3.96
COAL CONVERSION	3.99	1.69		1.86		6.03	2.13					10.45	
WIND CONVERSION		0.18	0.73		2.43		3.42	0.14				1.22	1.51
H. T. R.				2.32		6.14			0		6.02		
HEAT PUMPS			1.86		1.83			0.4			0.59		
IRON/STEEL INDUSTRY		0.89					0.33			0.86			
COAL COMBUSTION (FLUID, BED)						9.04				6.07		3.17	7.99
BIOMASS					3.93					2.28			
GEOTHERMAL						7.27			0.37				
WAVE ENERGY								0.09				1.98	
TRANSPORT									4.84	2.50			
ENHANCED OIL RECOVERY													4.43
SHALE OIL										3.21			
TAR SANDS		7.21											
CENTRALIZED SOLAR GENERATION						2.41							

TABLE 24

2000: OIL AND GAS SAVINGS FROM IMPLEMENTATION OF NEW TECHNOLOGIES

As a Percentage of IEA "Group of 13" Total Oil and Gas Usage

(PERCENT)

(Phase I Estimates Based on Six Technologies per country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.	TOTAL
SOLAR HEATING	0.007	0.005	0.020	0.084	0.008	0.368	0.031	0.001	0.013	0.003	0.005	0.034	3.345	3.93
INSULATION	0.044		0.063	0.067	0.038		0.050	0.016			0.005	0.176	0.313	0.73
WASTE HEAT (Coupled Production)		0.08	0.036	0.134	0.009		0.005				0.015			0.28
FAST BREEDER	0.057			0		0.141			0		0	0.470	2.066	2.73
COAL CONVERSION	0.077	0.12		0.134		1.052	0.053					0.547		1.98
WIND CONVERSION		0.013	0.006		0.007		0.010	0.001				0.064	0.788	0.89
H. T. R.				0.167		1.073			0		0.039			1.28
HEAT PUMPS			0.015		0.006			0.002			0.004			0.03
IRON/STEEL INDUSTRY		0.06					0.008			0.008				0.22
COAL COMBUSTION (FLUID, BED)						1.579				0.057		0.166	4.170	5.97
BIOMASS					0.012					0.021				0.03
GEOTHERMAL						1.262			0.011					1.27
WAVE ENERGY								0.001				0.104		0.11
TRANSPORT									0.142	0.024				0.17
ENHANCED OIL RECOVERY													2.312	2.31
SHALE OIL										0.030				0.03
TAR SANDS		0.52												0.52
CENTRALIZED SOLAR GENERATION						0.422								0.42

TABLE 25

2000: OIL AND GAS SAVINGS FROM IMPLEMENTATION OF NEW TECHNOLOGIES

		DISCOUNTED BENEFITS											
		GROSS (Billions of Dollars)						DOLLARS PER CAPITA ¹⁾					
		LOW ESTIMATE			HIGH ESTIMATE			LOW ESTIMATE			HIGH ESTIMATE		
DISCOUNT RATE		0%	5%	10%	0%	5%	10%	0%	5%	10%	0%	5%	10%
	SOLAR HEATING	5.92	2.98	1.60	14.8	7.49	4.05	2.90	1.46	0.79	12.5	6.30	3.41
	INSULATION	1.15	0.63	0.37	4.72	2.61	1.56	6.01	3.23	1.88	15.0	8.14	4.77
	WASTE HEAT (Coupled Production)	0.23	0.12	0.06	0.93	0.46	0.24	1.44	0.75	0.42	3.89	1.98	1.07
	FAST BREEDER	0.57	0.27	0.14	5.62	2.67	1.33	0.26	0.12	0.06	4.36	2.09	1.05
	COAL CONVERSION	1.91	0.98	0.54	6.40	3.11	1.59	1.78	0.91	0.50	9.48	4.60	2.35
	WIND CONVERSION	0.62	0.30	0.15	2.83	1.37	0.70	0.31	0.15	0.07	4.80	2.36	1.33
	H. T. R.	0.97	0.46	0.23	4.14	1.98	1.00	0.74	0.35	0.17	4.78	2.28	1.13
	HEAT PUMPS	0.02	0.01	Negl.	0.12	0.06	0.03	0.33	0.17	0.09	1.93	0.98	0.54
	IRON/STEEL INDUSTRY	0.08	0.04	0.02	0.32	0.17	0.10	0.35	0.19	0.11	1.40	0.76	0.44
	COAL COMBUSTION (FLUID, BED)	7.40	3.60	1.85	16.0	8.40	4.69	3.84	1.89	0.99	9.79	4.97	2.70
	BIOMASS	0.01	Negl.	Negl.	0.13	0.06	0.03	0.13	0.06	0.03	1.88	0.89	0.46
	GEOTHERMAL	0.50	0.25	0.14	3.99	1.93	0.99	0.35	0.18	0.10	2.78	1.35	0.69
	WAVE ENERGY	0.03	0.15	0.07	0.32	0.15	0.73	0.04	0.02	Negl.	0.49	0.23	0.11
	TRANSPORT	0.25	0.14	0.08	0.56	0.30	0.17	0.64	0.34	0.20	1.78	0.95	0.55
	ENHANCED OIL RECOVERY	3.50	1.93	1.16	14.2	7.71	4.53	1.24	0.68	0.41	5.03	2.73	1.60
	SHALE OIL	0.02	0.01	Negl.	0.10	0.05	0.03	0.15	0.07	0.03	0.94	0.50	0.28
	TAR SANDS	0.37	0.21	0.13	2.34	1.22	0.68	1.2	0.68	0.42	7.70	4.00	2.23
	CENTRALIZED SOLAR GENERATION	0.20	0.09	0.05	1.05	0.51	0.26	0.14	0.63	0.31	0.72	0.35	0.18

1) Per Capita for country concerned.

TABLE 26

2000: CHANGES IN NUCLEAR FUEL FEED REQUIREMENTS PER YEAR RESULTING FROM
IMPLEMENTATION OF NEW REACTOR TECHNOLOGIES¹

(METRIC TONS)

REACTOR	NATURAL URANIUM SAVINGS	THORIUM REQUIREMENTS
FAST BREEDER REACTOR ²⁾	2123	--
HIGH TEMPERATURE REACTORS ³⁾	458	270

- 1) The HTR was assumed to use 0.1015 MT Uranium per MWeY and 0.011 MT thorium per MWeY. It was assumed that the plant efficiency was 38.7% in deriving the uranium and thorium required for process heat. For the FBR, it was assumed that 1.619 kg uranium was required per MWeY. A 70% capacity factor was used.
- 2) Assuming a FBR installed capacity of 71800 MWe of which 16400 MWe replace an equal amount of other reactor types except HTR's; whereas the remainder increases the overall nuclear capacity and substitutes for fossil fuel supplies,
- 3) Assuming the Th-U-fuel cycle and an installed capacity of:
 - a) 21800 MWe which replace an equal amount of other reactor types except FBR's.
 - b) 34200 MW_{th} for process heat generation which substitute for fossil fuel supplies.

TABLE 27
1985; NON-RENEWABLE PRIMARY ENERGY SAVINGS FROM NEW TECHNOLOGIES

(10¹⁵ Joules)

(Phase I Estimates Based on Six Technologies Per Country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.	TOTAL
SOLAR HEATING	0	0,1	7	75	Negl.	59	0,23	Negl.	18,8	0,02	0,2	15	730	905
INSULATION	27		66	45	15		33,3	4,66			1,6	119	385	697
WASTE HEAT (Coupled Production)		1,2	18	35	1		1,5				0			57
FAST BREEDER	0			15		17			0		0	0	0	32
COAL CONVERSION	-5	0		0		0	-8,7					0		-14
WIND CONVERSION		0	3		Negl.		1,3	0				5	47	56
H. T. R.				0		61			0		0			61
HEAT PUMPS			4		Negl.			0,07			1,1			5
IRON/STEEL INDUSTRY		37,5					5,4			10,5				53
COAL COMBUSTION (FLUID, BED)						0				0		0	75	75
BIOMASS					Negl.					2,5				3
GEOTHERMAL						150			0					150
WAVE ENERGY								0				-		1
TRANSPORT									92,6	10				103
ENHANCED OIL RECOVERY													2000	2000
SHALE OIL										-4				-4
TAR SANDS		234												234
CENTRALIZED SOLAR GENERATION						0								0

TABLE 28

2000: NON-RENEWABLE PRIMARY ENERGY SAVINGS FROM NEW TECHNOLOGIES
(10¹⁵ JOULES)

(Phase I Estimates Based on Six Technologies Per Country)	BELGIUM	CANADA	DENMARK	GERMANY	IRELAND	JAPAN	NETHERLANDS	NORWAY	SPAIN	SWEDEN	SWITZERLAND	U.K.	U.S.A.	TOTAL
SOLAR HEATING	11	3.1	28	320	12.1	551	46.4	1,15	3.3	4.5	2.4	53	5000	6036
INSULATION	65		95	110	58		75.4	23			7.3	291	466	1191
WASTE HEAT (Coupled Production)		36.5	42	350	14		13.3				22.8			479
FAST BREEDER	3.7			200		210			0		75	917	2095	3499
COAL CONVERSION	-120	0		-250		-1196	-14.6					-318		-1899
WIND CONVERSION		0.3	26		11		32.3	1.34				95	1175	1341
H. T. R.				-175		958			0		31			814
HEAT PUMPS			11		8.5			3.43			5.7			29
IRON/STEEL INDUSTRY		96.2					12.3			20				129
COAL COMBUSTION (FLUID. BED)						-2759				0		248	405	-2106
BIOMASS					18					32				40
GEO THERMAL						1897			19.8					1917
WAVE ENERGY								0.8				155		156
TRANSPORT									213	35				248
ENHANCED OIL RECOVERY													3450	3450
SHALE OIL										-10				-10
TAR SANDS		781												781
CENTRALIZED SOLAR GENERATION						630								630

5. CONCLUSIONS

The composite data for 1974 and projections for 1985 and 2000 underscore an impending discrepancy between energy supply and energy growth aspirations for the "Group of 13" nations as a whole. Without the vigorous introduction of new and conservation technologies, the deficit between energy demand and supply assumes ominous magnitude. Conventional indigenous supply capabilities of the "Group of 13" appear to be inadequate to overcome the impending deficits. Balancing the energy budgets through increased imports of conventional fuels would require apparently unrealistic levels of imports relative to today's world production rates and known resources. Failure to meet targets for new nuclear capacity will greatly aggravate the problem. Either new energy technologies must be developed and deployed, and improved efficiency in energy usage and conservation measures vigorously pursued, or energy growth targets of the "Group of 13" cannot materialize.

Each participating country selected six new or conservation technologies for preliminary assessment. Therefore, the conclusions are limited in

scope by the restrictions to six technologies. Of course, consideration of a larger set of technologies, extension to a time period beyond the year 2000, and the effects of increasing energy prices would greatly alter this preliminary assessment. Also, the effects of conservation measures and saturation effects in demand have to a limited extent. Therefore, the results of the Phase I technology evaluations can only be viewed as likely to be exceeded.

At the end of the Phase I Program, the technological evaluations are too preliminary for an attempt at firm ranking of the options. In general, the potential contributions of most technologies considered separately appear small on the basis of the estimated implementation rates. The largest yields a maximum of <2% of the "Group of 13" total oil and gas requirements for 1985, and <6% in 2000. Of course, a vigorous R&D effort on selected technologies could increase these estimates. Considering the imbalance between demand and supply revealed in the projections (as disclosed by steadily increasing dependence on imported oil and gas) a vigorous cooperative R&D effort is clearly justified.