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ENERGY PROSPECTS IN GLOBAL AND NORDIC PERSPECTIVE

Lecture given at the NESU Energy Seminar, Reykjavík, Iceland, November 1979

Jakob Björnsson

OS79049/ROD17
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1 INTRODUCTION

Energy has recently become one of the most discussed topics in the world. Everybody discusses energy. Politicians, engineers and scientists, economists, environmentalists, industrialists - and the general public. This sudden and widespread awareness of the importance of energy to modern society, the importance of a commodity that until quite recently was taken for granted, has come about through the so-called energy crises, i.e. disruptions in the flow of energy, especially oil, to the veins of our industrialized societies and the concurrent dramatic rise in energy prices. We have abruptively been reminded that cheap and abundant energy is not just something that can be taken for granted from now to eternity; on the contrary, only through prudence, self-restraint and careful planning is there a hope for the energy future of mankind.

My topic here is energy prospects in both global and Nordic perspective. Since a meaningful treatment of the Nordic energy situation is possible only on a global background I will take the worldwide aspect first.

A great number of studies have been made in recent years of the future world energy situation. These studies are of a widely different quality and comprehensiveness. Perhaps one of the most penetrating and carefully executed study of this kind has been performed by the so-called Conservation Commission of the World Energy Conference, WEC. The findings of that study were published last year for the WEC by IPC Science and Tehcnology Press simultaneously in the United Kingdom and United States, in seven volumes, one of them a summary volume. I have therefore felt that the best approach to my theme here would be be to present an outline of the summary volume.

The World Energy Conference is an international organization in the field of energy, established in London as far back as 1924, and now encompassing nearly 80 National Committees in a equal number of countries spread all over the world. It comprises countries of widely different populations, state of development and political and economic structure. It includes developed and developing countries and countries with market economies as well as centrally planned economies; energy exporting as well as energy importing countries.

The Conservation Commission of the World Energy Conference, which undertook the study that I am going to outline briefly here, consists of about 20 senior experts in the various fields of energy from 14 countries. The Commission, in turn, set up 8 seperate Study Groups, also of a truly international composition, to dig deeper into separate aspects of the overall study, like energy demand, energy conservation, coal resources, oil resources, gas resources, nuclear resources, hydraulic resources and unconventional energy resources. In addition, separate Review Boards were set up to review the findings of the Study Groups. These findings, together with comments from the Review Boards, were then subjected to Panel Discussions at the 10th World Energy Conference, which took place in Instambul, Turkey, in September 1977, and was attended by over 3000 participants active in the field of energy from all over the world. It was on the background of all this discussion, in addition ot the Study Group reports, that the Conservation Commission prepared the final version of its reports.

I shall now touch upon individual aspects of the general energy issue in the Commission's reports. Reference will repeatedly be made to the Commission's Summary Report entitled "World Energy. Looking ahead to 2020. Report by the Conservation Commission of the World Energy Conference, WEC 1978", under the shorter name "World Energy".

2.1 Energy demand upto 2020

Before we start our discussion of energy demand we shall take a look at a few definitions.

By energy demand we mean the amount of primary energy, i.e. energy in the forms occurring in nature, required as input to the energy conversion and distribution systems of the world to provide the ultimate customer with his energy needs. The amounts of primary energy needed for this purpose will be expressed in Standard International Units (joules, J), using the gigajoule (GJ = 10^9 J) and the exajoule (EJ = 10^{18} J). The following conversion factors have been used:

1 tonne oil equivalent (TOE)	=	44 GJ
1 tonne coal equivalent (TCE)	=	29 GJ
1 m^3 natural gas	=	38 MJ

Nuclear and hydro primary energy are defined to be equal to the corresponding electrical energy generated divided by 0.35.

The projection of future energy demand is a difficult and complex task. Therefore, the Conservation Commission of the WEC found it necessary to consider several approaches to the projection of world energy demand by the year 2020.

For our purpose we may group the multitude of methods used to forecast future energy demand into two broad categories, viz.:

1. Extrapolation of historical trends
2. Energy models

Since the depreciation life of most energy related plans is as long as thirty to forty years and therefore tends to retard their replacement and the improvement in energy conversion and utilization efficiencies, it might appear justified simply to extrapolate past demand trends. However, the extrapolation is very sensitive to the historical period used as the basis for calculation, as illustrated by Table 1 and Figure 1.

Table 1 World primary-energy demand projection based on different historical periods

Historical period	*Annual rate of growth over period, % per annum*	*Primary-energy demand by extrapolation to the year 2020, exajoules*
1860–1975	2.0	700
1925–1975	3.3	1306
1933–1975	4.1	1918
1960–1975	4.3	2111

1 EJ = 10^{18} J

Source: Table 3, p. 15 in "World Energy".

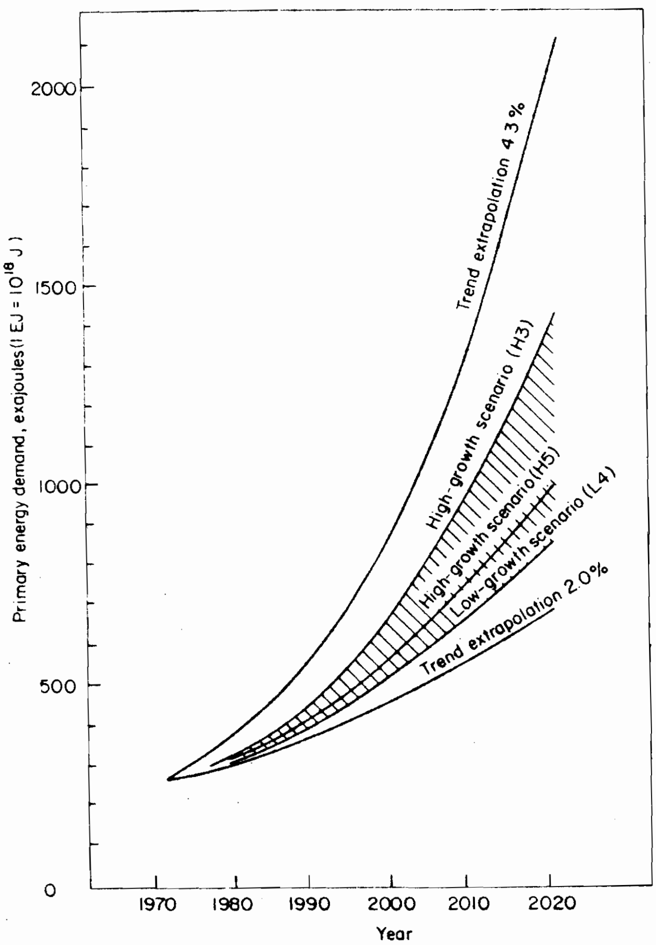


Figure 1 Primary-energy demand according to several projections

Source: Figure 3, p. 14 in "World Energy".

The range in extrapolated demand is much too broad for a reasonable representation of probable demand in the 2020. First, an energy growth rate of only 2% per year (1860-1975) produces a demand of only 700 EJ, which would barely support the needs of the expected increase in world population, so that the rate of energy consumption per capita would not provide for improved living standards for large segments of the world's future population. On the other hand, the effect of the growth rate of 4.3% per year (1960-1975) results in a demand of about 2100 EJ, which greatly exceeds even the most optimistic estimates of potential primary energy supply by the year 2020. This trend extrapolation technique, however, does serve to delineate a range, outside of which world energy demand is not likely to fall. Therefore, the Commission decided to base its projections on the use of energy models.

Basically, an energy model is a formal structure, usually in a mathematical form, relating energy demand to its causal factors. Now there is a multitude of uses to which energy is put in modern society and a corresponding variety in "causal factors". It is not surprising, therefore, that a great number of energy models has been constructed in the course of time. Since the oil price increases in 1973-74 there has been a true proliferation of energy models, some of which are highly sophisticated, but few, if any, go beyond 15-20 years.

The use of energy models has met with a highly varying degree of success, and there has been a lot of discussion and disagreement on their usefulness. This is not surprising. Models are but approximations to reality. The same reality may be represented by many different models, which may apply in different contexts. Reality is constantly changing and cannot forever be caught in an essentially static mathematical formula. Sooner or later all models break down. Some models have been made so complex and include so many variables as to preclude any empirical tests since the available data base is not sufficiently detailed.

As a rule of thumb the simpler an energy model can be made the better it is likely to be. This is especially true if the model is to be applied to long-range forecasting.

I said before that there is a multitude of causal factors behind modern man's use of energy. The relevance of individual factors to a particular situation may often be debatable. However, it is generally accepted that the use of energy is related to economic activity in its broadest sense. This conviction is firmly supported by empirical data, as Figures 2 and 3 show. Figure 2 shows the relationship between per capita gross national product (PNP) and per capita energy use of various countries, and Figure 3 the annual percentage change in energy use and GNP in USA 1947-1974. The close correlation between the changes in Fig. 3 is quite striking.

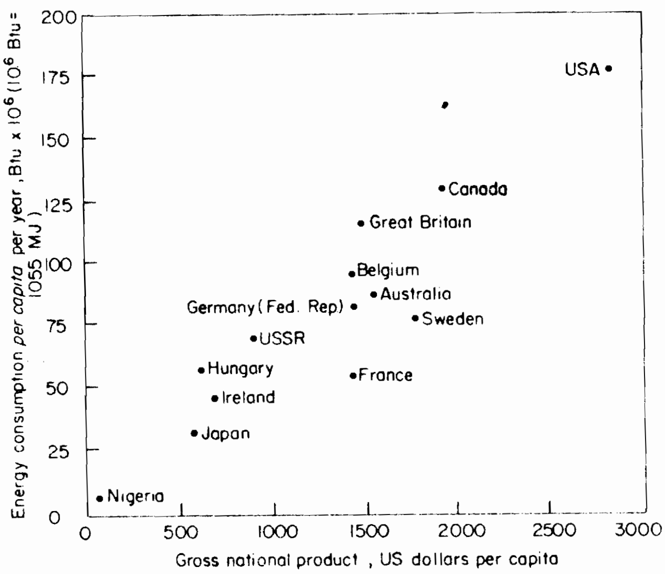


Figure 2 Relationship between energy consumption and economic activity. (Based on an original in Scientific American, *Vol.* 224, *No.* 3 (1971))

Source: Figure 2, p. 196 in "World Energy".

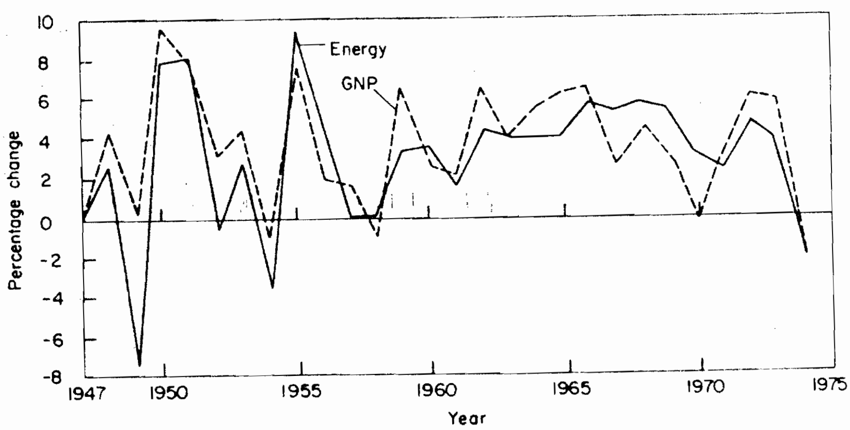


Figure 3 Changes in energy and GNP, 1947–1974. *Courtesy of the Bureau of Mines, US Department of the Interior*

Source: Figure 3, p. 197 in "World Energy".

The actual work of modelling world energy demand up to the year 2020 was entrusted by the Conservation Commission in March 1976 to Dr. Richard Eden and his co-workers at the Energy Research Group, Cavendish Laboratory, Cambridge, Great Britain. The Group prepared a report, known as the Cavendish Report.

This is a work of pioneering nature, for although energy models have often been used for individual countries or group of countries, no other serious attempts are known to have been made to analyse future energy demand <u>on a global scale</u> in such detail.

The Cavendish team used three different models for their study of world energy demand:

1. An energy demand model
2. An oil demand model
3. An inter-fuel substitution model.

Time does not permit a detailed discussion of the procedures used. I shall therefore restrict myself to a short mention of the first, the energy demand model.

The energy demand model used is an integrated version of the differential expression normally used in econometric analysis of supply and demand. It has the following form:

$$E(N) + F = \{E(1972) + F\} \cdot \left[\frac{Y(N)}{Y(1972)}\right]^{\gamma} \cdot \left[\frac{P(N)}{P(1972)}\right]^{\beta}$$

where

- $E(N)$ is the energy demand in year N.
- F denotes a parameter related to substitutions from non-commercial energy.
- $Y(N)$ denotes regional (or global) GNP in year N
- $P(N)$ denotes the internal price of energy in the region (or the world) in year N
- γ denotes the income elasticity (with respect to $E(N) + F$)
- β Denotes price elasticity

The internal price of energy, P(N), is related to the price of oil through a time-delayed response function.

For the purpose of the study, the world was divided into the following three regions:

1. The OECD countries
2. The centrally planned economies (CPE)
3. The developing countries

The model was applied seperately to each of them.

At this point I should like to draw attention to a very important fact, viz. that an energy forecast is not an end in itself. An energy forecast is merely a tool for policy analysis and decision making. By preparing several internally consistent and reasonably plausible pictures of the future, so-called scenarios, it may be possible to derive some scenario-invariant conclusions of importance for energy policy and decision making, and at the same time elucidate other decisions that are not scenario-invariant, i.e. which depend on individual scenarios. Making distinction between these two types of decisions, viz. scenario-invariant and scenario- non-invariant, as early as possible is extremely important to be able to make each type of decision at the appropriate time.

Accordingly, the Cavendish team produced a number of scenarios by making for each of the above three regions assumptions about:

1. Economic growth (growth of GNP)
2. Income elasticity, γ
3. The price of energy, P(N)
4. Price elasticity, β

It is impossible within the time frame of this lecture to go into details regarding the different scenarios produced by the Cavendish team. Figure 1 shows (as a hatched area) the range within which the various scenarios lie.

The findings of the Cavendish team were carefully scrutinized by the Conservation Commission itself, the Review Boards and also subjected to Panel Discussions at the 10th World Energy Conference in Instambul. Especially, the different demand scenarios were compared with the estimates of potential energy supply prepared by the Study Groups for individual energy resources. Obviously, if estimated demand exceeded potential supply for the world as a whole the rate of economic growth assumed could not be maintained with the income and price elasticities and energy price assumed. One or more of these assumptions, therefore, had to be changed.

The Conservation Commission, accordingly, produced a scenario of its own for inclusion in its final report, one that is consistent with estimated potential supply, the so-called Alternative Demand Scenario. The basic assumptions behind this scenario are summarized below.

<u>Economic growth:</u>

OECD regopn:	4.2% per year, constant
Developing countries:	5.7% per year, "

<u>Income elasticities γ:</u>

OECD region:	0.80 initially, tapering off to 0.40 in 2020
Developing countries:	1.30 initially, tapering off to 0.90 in 2020

<u>Price elasticities β:</u>

OECD region:	- 0.40 (constant)
Developing countries:	- 0.30 (constant)

<u>Internal price of energy:</u>

OECD region:	Constant annual increase 3% per year
Developing countries:	" " " 2% per year

For the centrally planned economics the following assumption was made:

> Average annual energy supply increases by 3.3% a year, and no export or import, i.e. self-sufficiency for the CPE-region as a whole. This should be quite sufficient to maintain the high level of economic growth experienced in most of these countries during the last three decades.

Figure 4 and Table 2 show the energy demand according to the Conservation Commission's Alternative Demand Scenario. Only commercial energy is shown (viz. excluding F in the model formula).

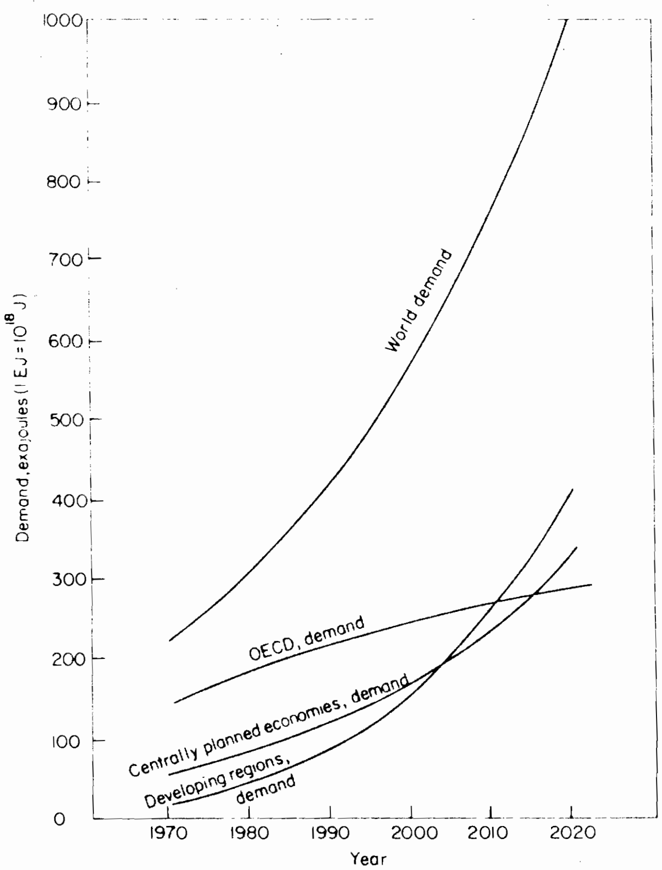


Figure 4 The Conservation Commission's Alternative Demand Projection

Source: Figure 4, p. 16 in "World Energy".

Table 2 Alternative Scenario demand projections

	Primary energy demand, exajoules			
	OECD	*Centrally planned economies*	*Developing nations*	*World*
1972	150	66	27	243
1980	178	86	46	310
1990	212	120	86	418
2000	242	167	152	561
2010	262	233	253	748
2020	278	325	397	1000

Note: Only commercial energy is shown in the projections.
1 EJ = 10^{18} J

Source: Table 4 in p. 17 in "World Energy".

It should be noted that a key issue in the demand projections of the Alternative Demand Scenario is the downward trend in income/energy elasticities for both the industrialized and the developing nations over the period 1985-2020. Without this trend, constant economic growth would require more energy than shown, which might exceed the potential supply. Exceeding the potential supply for the world as a whole, however, is a physical impossibility so that if the elasticicities do not decline the inevitable consequence is slower economic growth than assumed.

We now turn over to the potential energy supply.

2.2 Potential energy supply up to 2020

As previously stated, the Conservation Commission of the World Energy Conference set up a number of Study Groups to study the availability of various energy forms in the period up to the year 2020. Their findings will now be summarized.

The Commission starts its report by the following statement: "Known energy resources are greater today than at any time in history. Although large quantities of the world's oil and gas resources have been consumed, larger reserves remain than were envisaged forty years ago. Furthermore, in the same period, a new major energy resource - nuclear fission of uranium and thorium - has been discovered and used. The technological process that has discovered and produced these primary energy resources is still developing vigurously".

Despite all this there has developed a concern about whether there will be sufficient energy to extend the benefits of the industrial revolution to the nations of the world who have not so far enjoyed these benefits, while maintaining them for the nations who have done so. The real concern, probably, is whether there will be sufficient energy in time to accomplish this task at a rate that is acceptable to a great majority of mankind, especially the developing world, without a major disruption of social order and threat to world peace and security. The resource in short supply may be time rather than energy per se. Even if the necessary energy resources exist and man's knowledge of how to use them is expanding, the implementation of the necessary supply measures requires time. Meanwhile, the world has become heavily dependent on oil and gas - now both diminishing resources - which must, in the foreseeable future, be replaced by other energy resources. The necessary transition in today's massive worldwide energy-supply complex will test to the utmost man's capacity for organization, cooperation and implementation.

The composite production from individual resources determines the world's energy supply, and sets an upper limit to worldwide energy use. The findings of the Conservation Commission are summerized in Table 3, by resources and years, and graphically in Figs. 5 and 6

Table 3 Potential world primary energy production, exajoules (1 EJ = 10^{18} J)

Resource	*1972*	*1985*	*2000*	*2020*
Coal	66	115	170	259
Oil	115	216	195	106
Gas	46	77	143	125
Nuclear	2	23	88	314
Hydraulic	14	24	34	56
Unconventional oil and gas	0	0	4	40
Renewable, solar, geothermal, biomass	26	33	56	100
Total	269	488	690	1000

Source: Table 1, p. 9, in "World Energy".

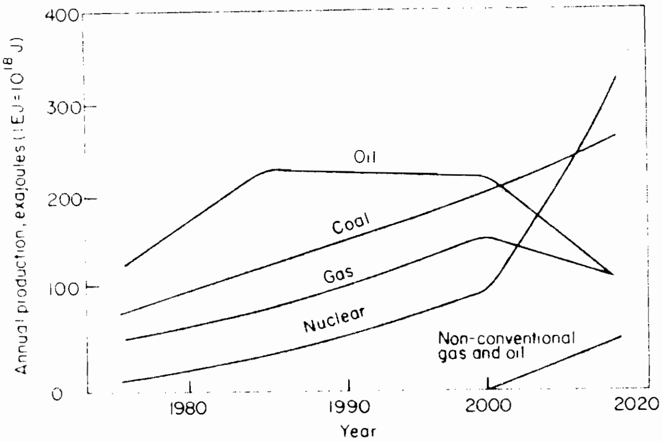


Figure 5 *Annual world primary-energy production from non-renewable resources*

Source: Fig. 1, p. 10, in "World Energy".

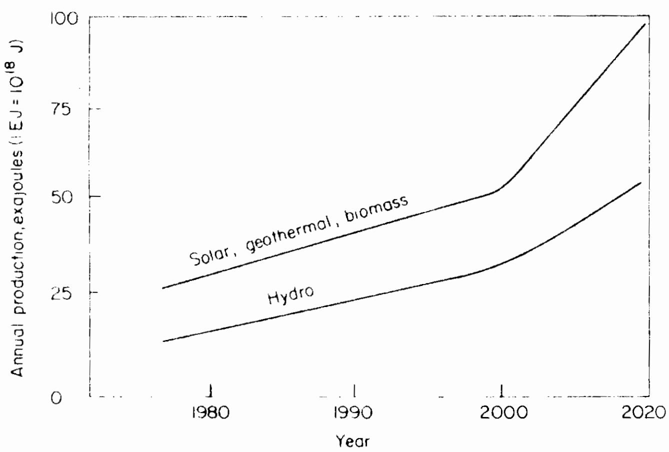


Figure 6 *Annual world primary-energy production from renewable resources*

Source: Fig. 2, p. 11, in "World Energy".

It is apparent from the table and the figures that burden of supply throughout the period is placed on the non-renewable resources, which are estimated to provide over 80% of the world's energy supply by 2020. Also apparent is a change in the supply spectrum from these resources. Coal and nuclear are expected to be the major suppliers of energy - over 55% of the total - coal having trebled its production and nuclear increased by a factor of 150. The combined supply of conventional oil and gas is expected to peak at approximately one- third of total energy supply by the year 2000. So-called non-conventional oil and gas resources may contribute another few percent of the total supply by 2020.

Today, energy from renewable energy resources is of the order of 10% of the world's annual energy supply. By 2020, their share is a about the same level.

Figure 7 shows a comparison between estimated potential world energy supply and world demand according to the Conservation Commission's Alternative Demand Scenario. It is seen that supply slightly exceeds demand throughout the period. This is reassuring, but must not be allowed to lull us into inactivity. In fact, it is by no means certain that the potential supply shown can actually be realized. Let us look a little closer at the prerequisites for realization, for each resource.

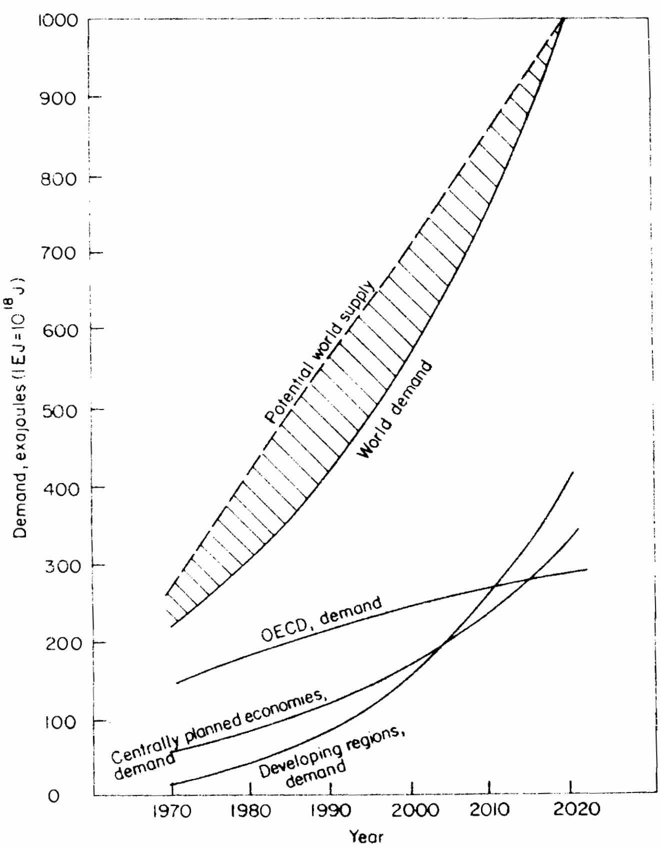


Figure 7 The Conservation Commission's Alternative Scenario

Source: Fig 6, p. 23, in "World Energy".

2.2.1 Coal

Recent studies of the availability of coal resources continue to support the expectation that they will be sufficient to meet the world's requirements for centuries to come. Even with the most demanding rates of world production, coal reserves should represent about two centuries of supply. For the period here considered, up to 2020, therefore, the challenge will be one of production and distribution, not resources. If coal is to play the role assigned to it in the findings of the Conservation Commission, a greatly accelerated programme of mine development and transport construction will be required. There is some concern that men, money and materials may not be committed in time to meet the growth in coal demand. A significant increase in production in the major coal-producing countries is possible only through establishing new principal mining centres in areas which are less developed industrially, in the west in USA and east of the Urals and in Siberia in the USSR.

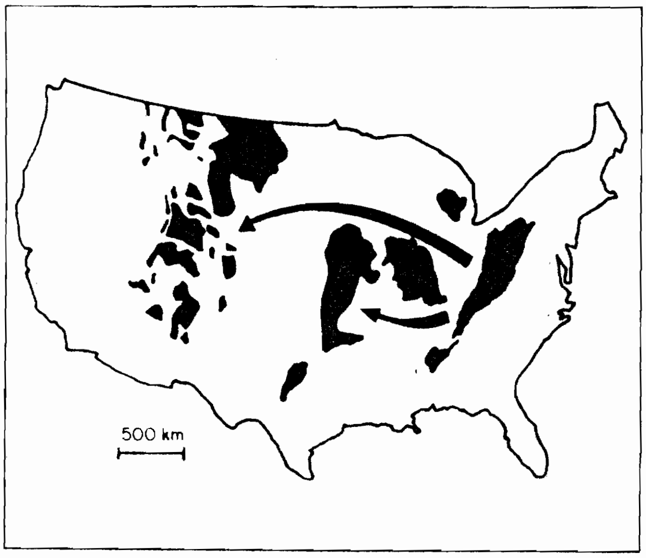
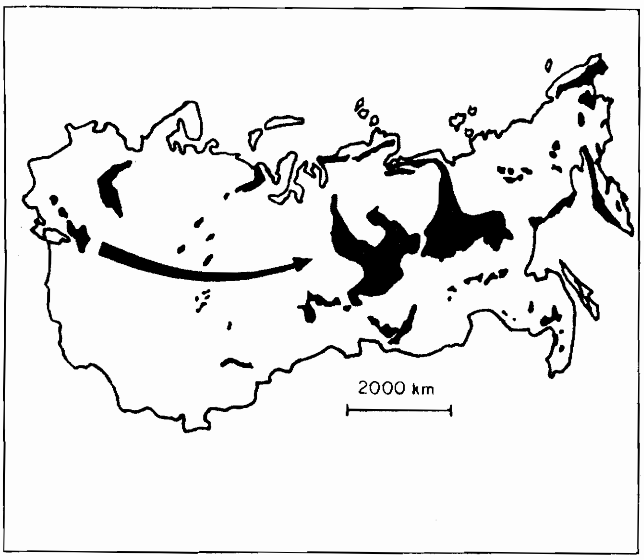


Figure 8 Future coal mining centres, USA

Source: Fig 22, p. 78, in "World Energy".



Source: Fig. 23, p. 79, in "World Energy".

Figure 9 Future coal mining centres, USSR

The future coal production as estimated by the Conservation Commission is shown in Tables 4 and 5.

Table 4 Estimated future production by the main coal-producing countries for 1985, 2000 and 2020

	Coal production in 10^6 t.c.e.			
Country	*1975*	*1985*	*2000*	*2020*
Australia	69	150	300	400
Canada	23	35	115	200
China (People's Rep.)	349	725	1 200	1 800
Germany (Fed. Rep.)	126	129	145	155
Great Britain	129	137	173	200
India	73	135	235	500
Japan*	19	20	20	20
Poland	181	258	300	320
South Africa	69	119	233	300
USA	581	842	1 340	2 400
USSR	614	851	1 100	1 800
Total	2 233	3 401	5 161	8 095

* Included because of its importance in international trade.

Source: Table 10, p 68, in "World Energy".

Table 5 Estimated future production by other coal-producing countries of the world

Country	*Coal production in 10^6 t.c.e.* 1975	1985	2000	2020
Argentina	0.7	3.0	6	8
Belgium	7.0	7.2	7	7
Botswana		5.5	11	16
Brazil	2.5	7.5	15	40
Bulgaria	13.6	18.7	30	35
Chile	1.5	2	6	8
Colombia	3.6	8	15	25
Czechoslovakia	80.0	93	100	110
France	23.4	14	14	14
GDR	74.6	80	90	100
Greece	6.0	14	18	20
Hungary	10	24	24	25
Indonesia	0.3	2	13	18
Mexico	7.1	20	42	45
North Korea	34.0	36	40	50
Romania	13.0	25	35	40
South Korea	18.0	24	20	20
Spain	12.3	25	23	25
Turkey	13	21	30	35
Venezuela	0.2	5.5	6	10
Yugoslavia	18.1	21	40	45
Other countries	21	26	34	55
Total	360	483	619	751
Main coal-producing countries	2 233	3 401	5 161	8 095
Total world production	2 593	3 884	5 780	8 846

Source : Table 11, p.69, in "World Energy".

The opening of mines at locations distant from industrial energy users will require the construction of sizable energy transport systems.

The required expansion in coal production and transportation facilities entail comparatively long lead times in constrast to the development of other fossil fuels, such as conventional oil and natural gas. The development of surface mines requires a minimum period of three to five years; that of an underground mine ten years from mine opening to full production, or maybe twelve years when the time to secure mining permits is included. These extended lead times, together with the immensity of the task, make a rapid response by the major coal-producing countries to the immediate supply of the world needs very difficult.

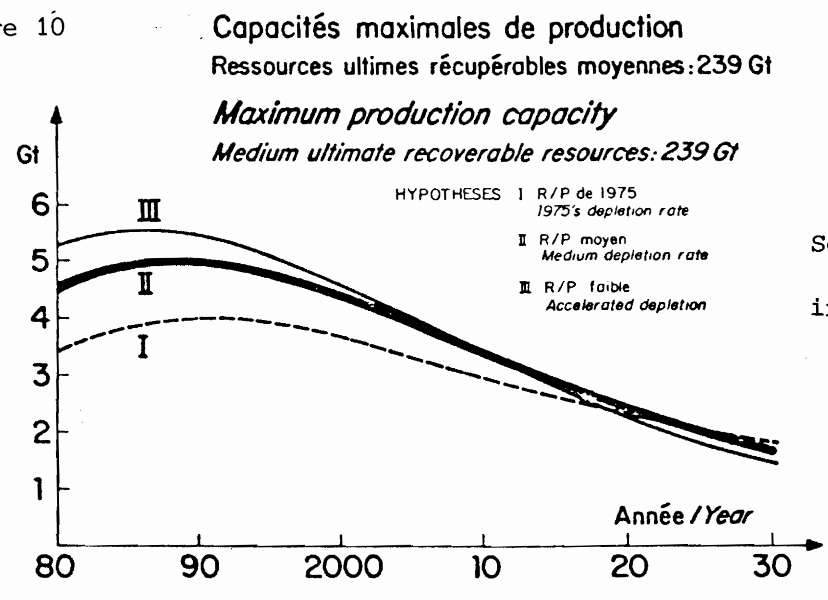
Decisions - major decisions - must therefore be made quickly - and implemented quickly, if the role assigned to coal is to be realized at the time here assumed. Time is here by far the most critical resource.

2.2.2 Conventional oil

In contrast to coal, the ultimately recoverable resources of conventional petroleum are severly limited. They are presently estimated at about 239 gigatonnes (Gt), or $1650 \cdot 10^9$ barrels. There is a number of uncertainties attached to such an estimate but time will not allow me to discuss them here. In addition, production rates, viz. the amount of oil taken from the ground per year, is dependent on a number of factors in addition to the estimated reserves at a particular time, some of them physical, but other political. I shall mention here only two, the discovery rate, viz. the amount of new oil discovered through exploration per year and added to the known reserves, and the depletion ratio, that is the ratio of reserves to annual production, which is primarily a political decision variable, at least in recent years it has become so.

The Conservation Commission has attemted to outline the possible maximun annual conventional oil production based on future discovery rates and a range of feasible depletion rates. The result of that attempt is shown by the middle curve in Fig. 10, that is based on so-called "medium depletion rate" which has been estimated at 35 for the Middle East and Africa and 10-20 for all other regions. A production ceiling of about 5 Gt/year is reached about 1990, whereafter production decreases to about 4 Gt/year in 2005 and 2.3 Gt/year by 2020.

Figure 10



Source: Fig. D, p. 27, in "World Energy Resources 1985-2020".

When looking at these findings of the Conservation Commission of the World Energy Conference regarding future oil production, the question is bound to come up how this production rate compares with estimated oil demand. Unless there is a reasonable balance oil prices are bound to rise to unprecedented heights, with dangers of severe disruptions in world economic order and perhaps social upheavals.

The Conservation Commission did look into this problem. The conclusion was that there probably will be sufficient oil from all sources, conventional and unconventional, to meet the world demand for oil at the turn of the century, and thus a hope of avoiding wildly exorbitant oil prices, but only if oil is reserved for specific uses where it is now indispensable, such as transport and the chemical industries. The use of oil for heating and power generation must be largely discontinued, and oil must be replaced by coal and nuclear energy in these sectors.

2.2.3 Non-conventional oil

This term is used to denote oil deposits which are hardly or not at all exploited today and which will require exploration and exploitation of technology that is not yet fully developed.
There sources include:

1. Deep offshore deposits
2. Polar deposits
3. Heavy oil deposits
4. Enhanced recovery from oil fields
5. Tar sands
6. Oil shale
7. Synthetic fuels from coal
8. Synthetic fuels from biomass

All in all, non-conventional oil deposits appear to be very large, much larger than those of conventional oil. The big question is technology and economics. It is concluded that without technological breakthroughs, production of non-conventional petroleum is unlikely to occur much sooner than 1990. The Conservation Commission estimates that development will be rather slow up to the turn of the century, but that production of non-conventional oil + non-conventional gas will increase tenfold in the first two decades of the next century.

In addition to technological and economic obstacles to the development of non-conventional oil deposits, reaching a peak production of about 4 Gt of conventional oil a year by 1990 and maintaining a sizable production for a long time thereafter, ableit smaller, is no easy task, and presents challenges in the field of international politics, which should not be viewed lightly. Not only is the decision to install the oil production facilities one of political importance to many oil-producing nations, but also the further decision to operate these facilities at high levels of production is becoming a very serious political issue, since production means export of a valuable resource patremony.

One of the principal challenges in oil, conventional as well as non-conventional, is to convince the world's policy makers that the decisions must be taken now to commit the required investment in capital and manpower to ensure an adequate future supply of petroleum. Failure to make these hard decisions will result in serious energy deficiences with grave social consequences in the last decade of this century and beyond.

Thus, although the Conservation Commission does foresee a balance between oil supply and (restricted) oil demand, that balance may be a very precarious one.

2.2.4 Natural gas from conventional sources

Total conventional gas resources are presently estimated at approximately 10 500 exajoules (EJ) or $2.8 \cdot 10^{14}$ m^3, or of the same order of magnitude as conventional oil. Production capability is a function of a number of factors, among which are the gas resource base available for production and the rate at which exploration and field development can proceed in a given region. On the basis of such factors, as well as many others, the Conservation Commission has estimated natural gas production capability as shown in Table 6.

Table 6 Estimated natural-gas production capability by region (exajoules or $ft^3 \times 10^{12}$) (1 ft^3 = 0.028 m^3)

Region	*1976** *Actual*	*1985* *High*	*2000* *High*	*2000* *Medium*	*2020* *High*	*2020* *Medium*
North America	23.0	29.7	27.3	26.6	10.7	7.5
Western Europe	6.4	9.6	8.7	8.4	2.2	1.6
JANZ†	0.3	0.4	2.1	2.1	4.6	4.5
USSR; East Europe	12.8	21.8	55.7	55.6	28.5	25.3
China; other Asia	1.4	1.7	2.9	2.9	6.1	6.0
OPEC, Group 1	0.5	7.0	18.1	18.1	17.7	16.4
OPEC, Group 2	3.4	4.9	21.3	21.3	45.6	44.6
Central America	0.9	1.1	2.3	2.2	1.6	1.4
South America	0.8	1.1	2.2	2.2	4.8	4.7
Middle East	0.1	0.5	1.0	1.0	0.3	0.3
North Africa	0.2	0.3	0.5	0.5	0.5	0.4
Africa, south of the Sahara	0.1	0.1	0.2	0.2	0.1	0.1
East Asia	0.1	0.1	0.2	0.2	1.6	1.6
South Asia	0.3	0.5	1.0	1.0	0.7	0.5
World total	50.3	76.8	143.5	142.3	125.0	114.8

* Rounded. Based on *Oil and Gas Journal*, 75(4), p. 95 (1977)

† Japan, Australia, New Zealand

Note: High – based on high price trend
Medium – based on medium price trend

Source: Table 5, p. 57, in "World Energy".

These projections are, among other things, based on

1. Estimates of cumulative gas production to date for each of the regions listed.
2. Estimates of in-place reserves
3. Appropriate finding rates and depletion rates

The words "high" and "medium" in the table refer to a gas price equivalent to 20 and 14, respectively, 1974 dollars per barrel of oil.

Under the "high" price scenario it is thus estimated that world gas production could rise from the present level of approximately 50 EJ to 77 EJ by 1985 and to a peak of about 143 EJ by the year 2000 for then to decline to about 125 EJ by 2020. At that time, about 50% of the presently estimated conventional gas resources will have been produced.

If natural gas is to play the role envisaged by the Conservation Commission, international trade in this commodity will have to expand greatly, since the production capability in some regions may greatly exceed demand, while the reverse will be the case in others. The potential production capability of the USSR, China and OPEC countries will in the near future greatly exceed both their demands and the requirements of importing regions. However, by the year 2020, only the OPEC countries will have production potential exceeding indigenous demand. It appears that the gas production capability of the OPEC countries may be capable of meeting the requirements of other regions to the year 2020, provided that the international transportation and distribution facilities exist.

Important factors in achieving the projected natural gas production capability are:

1. Gas price
2. Ability to finance exploration, development, transport and distribution
3. The economical and political environments

The price must be high enough to ensure that drilling costs are covered, yet low enough to remain competitive with the delivered price for alternative energy sources.

Huge projects will have to be planned, designed and constructed before projected supply can become an actuality. For example:

the 1340 km 1.22 m and 1.42 gas pipeline connecting Iran with the USSR

the 2976 km Oranberg pipeline from the Urals to Eastern Europe

the 4022 km pipeline from the USSR to Czechoslovakia and the Federal Replublic of Germany

the projected 7723 km pipeline system transporting Alaskan gas to markets in the lower 48 states of the USA.

Lastly, there have to be non-restrictive government policies for import and export of gas, if demand is to be met.

In the final analysis, therefore, the worldwide supply of gas will depend on both political and economic decisions.

2.2.5 Non-conventional natural gas

The production capability estimates of the last section (Table 6) do not include potential production from so-called non-conventional natural gas resources such as:

1. Methane from coal beds
2. Gas from shales
3. Geopressurized gas
4. Gsa from petroleum and coal conversion
5. Gas from bioconversion

Taken together, these resources may be very large, but they are to a great extent unknown.

The Conservation Commission has estimated the gas production potential from these resources as shown in Table 7.

Table 7 World gas from non-conventional sources (exajoules or $ft^3 \times 10^{12}$) ($1\ ft^3 = 0.028\ m^3$). Production potential

Source	*1985*	*2000*	*2020*
Coal beds	0.01	0.15	2.7
Shale	0.01	0.10	2.6
Tight formations	0.05	0.70	4.4
Geopressured formations	0.03	0.45	3.9
Biomass conversion	Negl.	0.10	0.9
Total	0.10	1.50	14.5

Source: Table 6, p. 59, in "World Energy".

2.2.6 Nuclear resources

In addition to making the forecasts of primary energy demand that have been shortly described above, the Conservation Commission also made forecasts for certain forms of secondary energy. Of these, only electricity will be mentioned here.

The production of electrical energy is estimated to have increased about eightfold by 2020, compared to an about fourfold increase in primary energy. This corresponds to an average growth rater of about 4.4% per year for the world as a whole. For comparison, the average growth rate of electrical energy production was 6.85% per year in USA in the period 1960-1975 and has been 11.5% per year, on the average in India since the 1950s, and is there expected to continue to advance by about 10% per year during the next three decades. In all regions of the world electricity is now regarded as a high-preference energy carrier, environmentally benign and of very general applicability.

Table 8 shows the estimated world electrical demand.

Table 8 Estimated potential world electrical demand (exajoules electrical output)

World regional groupings	*1972*	*2000*	*2020*	*Average growth rate 1972–2020*
OECD countries	14.1	40	77	3.6%
Centrally planned economies	4.7	28	64	5.6%
Developing countries	1.7	9	32	6.3%
Total	20.5	77	173	4.5%

Source: Table 17, p. 93, in "World Energy".

The eightfold increase in electridication envisaged by the Conservation Commission will have a most dramatic impact as evidenced by the fact that by 2020 it is expected that nearly half of the primary energy then produced will be converted to electric energy.

How is all this electricity to be generated? From what has already been said it is obvious that oil and gas cannot be counted upon to do the job; on the contrary: today's oil-fired generating plants will have to be shifted over to coal. As will be seen later, hydro can provide only a relatively minor part of the electricity requirements, and unconventional sources like solar, geothermal, wind, waves and fusion *will not* be able to taka a big share either in the next 40-50 years, whatever their potential may be in a more distant future. The lion's share of electricity production in the period up to 2020, therefore, will have to be borne by coal and nuclear.

With the potential production of coal in the period up to 2020, already discussed, coal alone will be unable to bear that part of the increased electricity production which hydro and unconventional resources cannot provide. For this period therefore there is no escape from the use of fission nuclear energy. Either we have to accept nuclear or we simply cannot generate all the electricity we want. For a more distant future, however, the conclusion may be different.

The resulting role of nuclear energy in the world energy production, as estimated by the Conservation Commission, was shown in Table 3.

The size of the nuclear resources available to meet these requirements for nuclear energy is shown in Table 9, which shows the estimated resources of uranium recoverable at a cost not exceeding 130 US (1977) dollars per kg of uranium in the world outside the USSR, China and Eastern Europe. Some 70% of the figures in the table are believed to be recoverable at costs up to $ 78 per kg, and thus can be viewed as being of economic interest today.

As with other energy resources, production capability depends on a number of factors besides resource availability. The present capability is about 33000 t/year, outside the centrally planned economies, for which data is not available. Beyond 1980 known resources are believed to be capable of supporting a maximum level of production approaching 110 000 t/year of uranium. Unless major new resources of uranium are discovered production capability is expected to decline.

Table 9 Estimated world resources of uranium (tonnes)

World region	*Resources*	
	Reasonably assured	*Estimated additional*
North America	825 000	1 709 000
Western Europe	389 300	95 400
Australia, New Zealand and Japan	303 700	49 000
Latin America	64 800	66 200
Middle East and North Africa	32 100	69 600
Africa south of the Sahara	544 000	162 900
East Asia	3 000	400
South Asia	29 800	23 700
Total	2 191 700	2 176 200

Note: Estimates are based on recovery costs up to $130/kg U (US$ 1977)

Source: Table 15, p. 87, in "World Energy".

The uranium production required to sustain the estimated nuclear generation of electricity is strongly dependent on future reactor types and fuel cycles. To study this problem the Conservation Commission envisaged altogether five different reactor type/fuel cycle scenarios. The following two illustrate the range in thinking in this context:

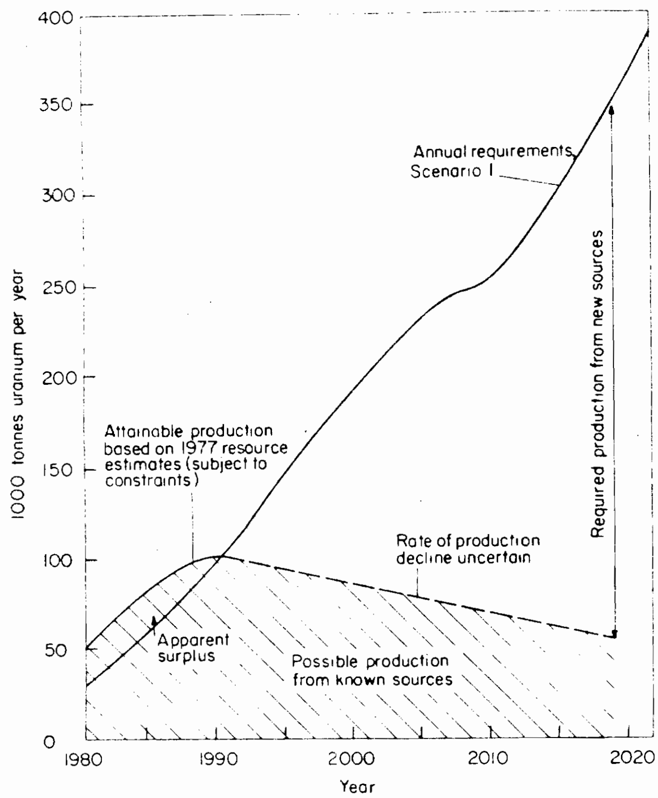
Scenario 1

This is a basic case, using light-water reactors initially, but installing commercial breeder reactors with a fuel doubling time of 24 years. The breeder reactors are installed beginning in 1987 in Western Europe, 1993 in North America, 1995 in the USSR and in 2000 in Japan.

Scenario 2

This is a "no reprocessing" scenario. In this case, only thermal converter reactors are installed in all regions. Light-water characteristics are used for these converters, since this is the most prevalent commercial reactor type in use today.

Figure 11 is a schematic illustration of the world's uranium supply problem 1980-2020, if Scenario 1 is assumed. For scenario 2, requirements would be higher from 1987 on.



Source: Fig. 28 p.96 in "World Energy".

Figure 11 *Schematic illustration of world uranium supply problem*, 1980–2020

It is apparent from the figure that from about 1992 an increasing part of the requirements will have to come from uranium production from new sources which still have to be discovered and from improvements in fuel utilization above the present level. Such improvements may come from new enrichment techniques with lower tailings losses, through recycling of uranium and plutonium in light water reactors; plutonium recycling in heavy water reactors and last but not least from use of more advanced fuel cycles. However, all advanced fuel cycles require fuel reprocessing, remote fuel fabrication techniques and permanent waste storage in addition to the conventional "front end" of the fuel cycle. Partly because of the long lead times involved, fuel enrichment and fuel reprocessing could become bottlenecks in the commercial development of nuclear power.

It is therefore fairly obvious that more uranium has to be found if nuclear energy is to play the part in the world's energy supply that is foreseen by the Conservation Commission. It is concluded that this problem is not likely to be one of the existence of resources. After all, prospecting for uranium is a rather recent activity which to date has been confined to only a small part of the world, mostly North America. Rather, it is likely to be, again, a problem of time. Under the favourable assumption of Scenario 1, the uranium supply industry is being asked to increase its level of production by a factor of fifteen in less than 45 years. in view of the ever-increasing number of constraints and the lengthening lead times, the 45-year period seems all too short.

It is clear that achieving the projected levels of uranium production becomes a challenge calling for unprecendented levels of effort and international cooperation. Urgent action is required to promote the development of both uranium resources and nuclear technology.

2.2.7 Hydraulic resources

Hydraulic energy, the energy of flowing water, is one of the natural energy resources that was first used by man, in water wheels for grinding and pumping. In the early days of electricity hydraulic energy provided a substantial part of it. Thus, in 1925, this resource accounted for about 40% of the electricity generated in the world, or 0,29 EJ. The installed hydro-electric capacity was then about 26 400 MW.

Today, the annual hydro-electric production is about 5.7 EJ and installed capacity about 372 000 MW or 372 GW. This production, if carried out in oil-fired plants, would require yearly $2.5 \cdot 10^9$ barrels of oil, or $6.5 \cdot 10^6$ barrels a day. The relative contribution of hydraulic energy to total electricity generation, however, has dropped from 40% in 1925 to 23% today.

The greater part of the economically attractive hydro sites in the industrialized nations have already been developed. With very few exceptions like Iceland and Norway the sites yet undeveloped are rather remote, and the construction of dams and powerhouses will be quite costly. On the other hand, the developing nations have large potential hydro capabilities, and in some areas of Asia, Africa and South America, they will provide a significant portion of the total energy requirements for these areas.

The Conservation Commission envisages extensive hydro-electric development during the next few decades. At present hydro-electric energy appears to be the most feasible, and in many areas, the most economical of the renewable primary energy sources for electric power generation, and thus efforts to develop additional production from this source will be increased.

The overall potential for hydro-electric generation is shown in Fig 12, in terms of total <u>installed</u> and <u>installable</u> capability. The probable hydro-electric production, in exajoules, as estimated by the Conservation Commission, is shown in Table 10.

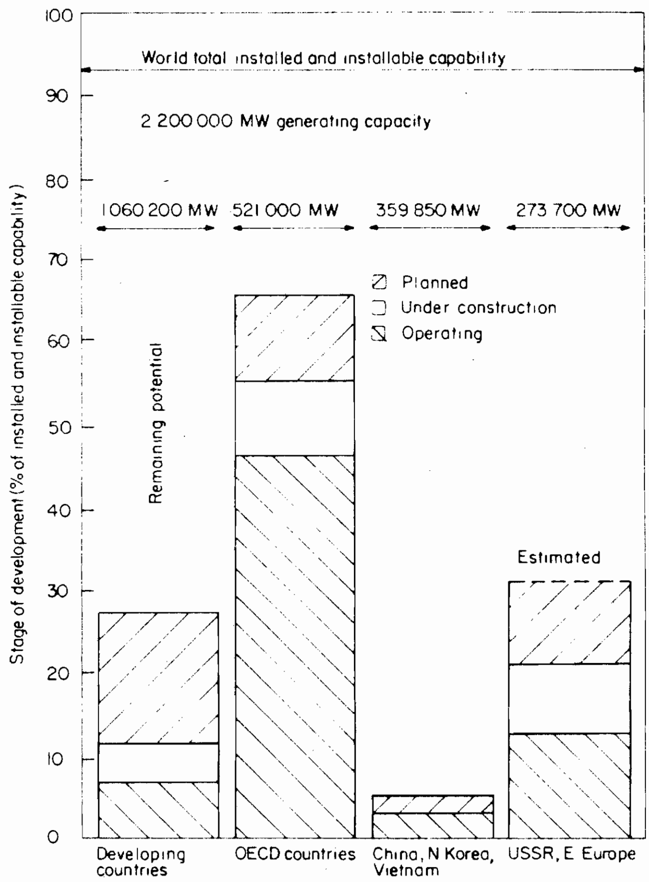


Figure 12 World total installed and installable hydraulic capability (2 200 000 MW generating capacity)

Source: Fig. 30, p. 105, in "World Energy".

Table 10 Estimated probable hydroelectric development

Country groupings	*Potential energy in exajoules (1 EJ = 10^{18} J)*			
	1976	*1985*	*2000*	*2020*
OECD countries	3.78	4.49	5.37	7.80
Centrally planned countries	0.72	1.20	2.88	8.70
Developing countries	1.17	1.97	4.49	11.80
World total	5.67	7.66	12.74	28.30

The figures shown are the probable annual average energy from installed hydroelectric facilities for the year indicated.

Source: Table 25, p. 106, in "World Energy".

From Table 10 we see that hydro-electric energy production is expected to increase fivefold up to the year 2020. Since total electricity generation is estimated to increase faster, the relative contribution of hydro will drop from 23% at present to 16% by 2020. It is also evident that most of this development will take place in the developing countries which will increase their production tenfold while the OECD countries will double theirs.

The 28.3 EJ of electricity estimated to be generated in 2020 corresponds to about 80% of the total estimated developable hydroelectric resources in the world. It is also equivalent of $34.5 \cdot 10^6$ barrels of oil per day, or nearly four times Saudi Arabia's present oil production rate.

There are a number of factors which make hydraulic energy attractive for future energy supply. Among them are:

1. It is a resource that is continuously renewed by the energy of the sun, which creates a sustained hydrologic cycle.
2. Hydro-electric energy can be an important part of multipurpose utilization of water resources.
3. Hydroelectric energy can be made available in remote areas of developing countries, becoming a catalyst in economic development of other resources and improving living conditions.

4. The flexibility and dependability of hydro-electric generation makes hydro-electric energy storage the most economical and practical of large-scale storage systems.

5. Today's remote control of hydro-electric plants, especially in the developed countries, makes for more efficient use of energy. Such technology also helps to make operation of small plants again economically feasible.

6. The evaluation in high-voltage technology, where voltages of over a million volts are now under consideration, and the development of HVDC transmission technology may make feasible and increasing numer of very large and remote hydro-electric projects.

But there are also factors tending to retard development as for instance:

1. Financing, which may be a very significant problem for the developing countries.

2. Future needs for water for purposes which are incompatible with maximum power generation, such as irrigation.

3. Environmental pressures for the preservation of free-flowing streams and water fowl habitat.

4. Social opposition to settlement relocation.

5. Legal problems and problems of international cooperation for the development of international rivers and river basins.

Great efforts are required to remove these obstacles to the maximum utilization of an energy resource that is inexhaustible at a time when prospects of exhaustion threaten continued reliance on oil and gas.

2.2.8 Unconventional renewable resources

This name covers a variety of energy resources with the common attribute that their share in the present energy production is minor or nonexistant. Hence the name "unconventional". The principal constituents are:

1. Solar energy
2. Geothermal energy
3. Nuclear fusion energy
4. Gravitational energy (tidal energy)

The first, solar energy, may be further subdivided into a number of components according to the form in which solar energy manifests itself, like

- direct solar radiation
- indirect diffuse solar radiation
- wind
- waves
- ocean temperature gradients
- ocean currents
- biomass (photosynthesis)

Solar and gravitational energy will both be available over the life of the solar system and are thus truly renewable, while geothermal and nuclear fusion energy will not be renewed at a rate commensureable with exploitation. A better name would probably be inexhaustible resources, since the resource base is so immense that exploitation would hardly affect it. On a human time-scale, however, the distinction is immaterial.

In fact, hydraulic energy is also a form of solar energy, but since its exploitation has reached a high level of development it is usually not counted among the forms of solar.

The various forms of unconventional renewable energy resources are in a very varied stage of development, in spite of the common feature that their contribution is minor. Thus, geothermal energy - some forms of it - has been utilized for a very long time while even the scientific feasibility of nuclear fusion has not yet been demonstrated - let alone its technical and economical feasibility. In fact, we here in Iceland find it very strange to count geothermal as an unvonventional resource. However, at a closer look we realize that although the form of geothermal that we are susing here to heat our houses, viz. energy from hydrothermal systems, i.e. hot water systems, is in fact fairly conventional in our eyes, the same is not true of other forms of geothermal energy, like the energy from petrothermal or hot dry rock systems; geopressurized systems etc. which may constitute a major part of the world's total geothermal resource base.

The resource base of some of the unconventional renewable energy resources is truly immense, although poorly known in many instances. Thus the amount of energy reaching the earth's atmosphere from the Sun is equivalent to 5 million exajoules per year, or 5000 times the estimated total world energy supply in 2020, from all sources. Similarily, the estimated total geothermal resource base is over 40 million exajoules and the energy supply from the complete utilization of the deuterium in the earth's waters in a fusion reactor is equivalent to $11 \cdot 10^{12}$ EJ.

The Conservation Commission has subjected the unconventional renewable resources to a very detailed study. Time does not permit me to do more than present the main conclusions, seperately for individuel resources since they are in an extremely different stage of development and their potentialities within the time-span considered here, up to 2020, are also very different.

Solar energy

It is estimated that simple applications of solar energy to water heating and space conditioning are not likely to displace more than 2-5% of the world's primary energy requirements over the course of time, and it is unlikely that they will reach this stage by the year 2020.

It is conceivable, although highly conjectural, at this stage, that solar generation of electricity, by means of thermal-electric conversion and photovoltaic energy conversion (solar cells) could amount to 10-15% of the electricity produced globally by the year 2020.

It is considered premature to estimate the potential contribution of solar-generated hydrogen to the world's energy needs for the year 2020, but the matter deserves continued attention together with an extended research and development effort. Present estimates, admittedly crude, for the cost of producing hydrogen by solar-chemical means range from $ 40 to $ 80 per barrel of oil equivalent.

The contribution of wind and wave energy on a global scale is expected to be very small, although on a regional basis, where conditions are particularily favourable they may become a significant energy source. Today, wind generators cost two to four times more than conventional generators of equivalent rating.

The potential ocean thermal energy conversion is considered as somewhat speculative at this time for the period here considered.

Biomass is today a significant energy resource, especially in the developing countries, representing about 10% of the world's primary energy production. It is expected to continue to play an important role in the future too in these countries for generation of process heat and synthetic fuels. There is a very considerable room for improvement in the efficiency of this energy conversion since the efficiency of conversion of firewood and dung into useful energy is of the order of 3-5% in the developing countries today, compared with around 20-35% for modern fuels and energy using equipment in the industrialized countries.

Land availability for energy plantations is believed to be a serious limiting factor in the development of biomass energy conversion systems.

It should be noted that today's use of firewood and dung in the developing countries is not counted as "commercial energy" and is not included in Table 2.

Geothermal energy

The world's geothermal-electrical capacity amounted to 1325 MW in 1976.

Table 11 shows the worldwide geothermal resource base, computed as the total heat contained in sub-surface rock and fluids to a depth of 3 km at temperature above 15°C, as well as the portion considered available for non-electrical (thermal) and electrical use, based on today's technology.

Table 11 Worldwide geothermal resource base, derived by computation (exajoules (thermal) × 10^3)

Temperature range, °C	*Total resource base*	*Thermal potential*	*Electric potential*
<100	36 000	2600	0
100–150	3 800	270	0
150–200	1 100	68	17
>250	73	3.5	0.9
Total	40 973	2941.5	17.9

Source: Table 28, p. 127, in "World Energy".

It is concluded that geothermal resources could play an increasing role in the world's overall energy supply and that countries fortunate enough to be located in the major geothermal belts of the world may be able to obtain a significant fraction of their energy requirements from these sources. Even in countries underlain by normal temperature gradients, geological, climatological and economic circumstances may combine to create a favourable setting for the use of subterranean heat.

Nuclear fusion

There is a widespread belief among the scientific community that the scientific feasibility of nuclear fusion will be achieved within the next 5-10 years by one or more of the several approaches under current investigation. It is concluded that the potential contributions of fusion power are great and could even be commanding in the course of time. However, the state of the art is still embryonic and it would be premature to say with any conviction when fusion might begin to enter the commercial energy markets in a serious way.

Concluding remarks about unconventional renewable resources

In spite of the bright prospects that some of the unconventional renewable resources hold for a more distant future, it is nevertheless the conclusion of the Conservation Commission's study that their role in the world's energy supply in the period up to 2020 will be fairly modest, 7-10% of the total (Table 2). The reason is that much development work and even research is needed before these resources can make a significant contribution and this takes time. This is a very important point, which is often forgotten in today's energy debate. It took a very long time - over a century - for petroleum to reach its present dominant position in the energy markets. Much of it was reached in the last few decades of the period; the progress was by no means uniform. We have to remember that the year 2020 is only 41 years off.

This fact is clearly demonstrated by an exercise that may be carried out with one of the models used by the Cavendish team, the so-called Fisher and Pry market penetration model. Let us optimistically assume an immediate breakthrough in any (or all) of these new technologies so as to provide, at competitive prices, electric energy, process heat and a suitable energy vector for the transport sector, like methanol. Let us further assume that through a major development and demonstration programme the new energy alternative has be 1985 captured a 1% share of world primary energy production or about 4 EJ, roughly equivalent to the whole world's currently installed nuclear capacity (which, incidentally, has almost three decades of development behind it). Let us further assume that owing to its superior characteristics, the new alternative will penetrate the market twice as fast as oil and gas did in the expansive 1950s and 1960s (which would imply an enhanced depreciation of the energy-related capital stock - certainly a very expensive programme). The new alternative would then, under these very optimistic assumptions capture some 2.5% of the market by the year 2000 and 10% by 2020.

In view of this exercise it may be argued that the Conservation Commission is overly optimistic in assigning to the unconvertional renewable resources a share of 100 EJ by 2020 - almost equal to the whole world's petroleum production in 1972.

The basic conclusion, therefore, is: The unconventional renewable resources hold a great promise for man's energy future and their development should therefore be pursued vigorously. But we must not expect them to solve our immediate energy problems.

Again: Time - not energy - is the resource in really short supply.

2.3 Energy conservation

Energy conservation has become a fashionable phrase today. It is one of the expressions which may mean different things to different people. A definition is therefore required at the outset.

Energy conservation as used by the Conservation Commission of the World Energy Conference means achieving the same result with less energy use. In other words: Rationalizing the use of energy; improving the efficiency of use.

Implied in this definition is elimination of waste, since waste does not contribute anything useful. On the other hand this definition does not mean achieving less results through reduced energy input, lowering our material standard of living.

I mentioned previously the assumptions behind the Conservation Commission's Alternative Demand Scenario. One of these assumptions was a decline in the so-called income elasticity, γ, from 0.80 to 0,40 for the OECD region and from 1.30 to 0.90 for the developing nations. Let us look at little closer at what these assumptions really mean.

The income elasticity means the percentage change in energy input to the national economy that is associated with a 1% increase in GNP. Lowering the elasticity from 0.80 now to 0.40 in 2020, therfore, in effect means that we are assuming an increase in energy input in 2020 per unit increase in GNP of only half of what it is now. In other words that we can achieve the same result (1% increase in GNP) in 2020 with only half the relative amount of energy that we now spend for it. This is precisely what energy conservation is all about. A sizeable amount of energy conservation is therefore imbedded in the basic assumptions behind the Alternative Demand Scenario, the base case for

the study. This conservation is greater for the industrialized OECD region than for the developing world, 50% reduction in relative energy input compared with 31%. We also noted previously that energy demand, according to the Alternative Demand Scenario was only slightly below the estimated potential supply. Had an unchanged γ been used, the assumed rates of economic growth could, other things beeing equal, not have been achieved within the limits set by potential supply.
In other words, a sizable conservation of energy is a prerequisite for achieving an economic growth of 4.2% per year in the OECD region and 5.7% per year in the developing region between now and 2020.

How is this energy conservation to be realized?

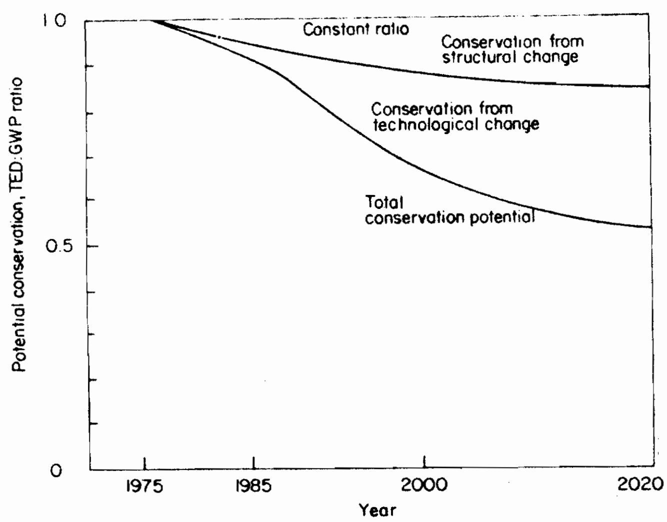
The reduction in energy use per unit GNP will be of a two kinds:

1 Resulting from technological change in industry, transport and other energy consumption sectors, i.e. improved energy utilization brought about by technological developments

2 Resulting from changes in the structure of GNP.

The Conservation Commission estimates that about 30% of the energy that would otherwise have been used by 2020 may be saved through the first type, technological development and improved energy conversion and utilization efficiencies. This type of saving can be achieved in all sectors of the world's economy - transport, industrial, commercial, domestic and energy conversion. In addition the Commission estimates that possibly another 17% saving may be achieved through structural changes in the more mature economies, viz. evolution from industrial to post-industrial societies where services rather than industries provide a gradually larger part of the GNP. Services are normally less energy-intensive per unit of output than industries. Also contributing to this latter type of saving are saturation effects in the highly developed economies such as in car transport and domestic appliances.

Figure 13 shows projected world conservation potential by year.



Source: Fig. 5, p. 18 in "World Energy".

Figure 13 Projected world conservation potential by year. TED, total energy demand; GWP, gross world product

Conservation of energy is a matter for industrial public and government concern. It is no longer possible to coninue patterns of energy use or to use energy-consuming processes which were economic in the recent era of abundant and inexpensive energy supply. The key to the successful application of conservation measures is to be found in making constructive decisions and initiating timely implementation programmes. There is considerable scope for energy economy in the very short term through "better housekeeping in energy use". There are other measures, supported by technological development which can be achieved only through medium term modernization programmes. Finally, there are the very long-term energy substitution programmes requiring new and unconventional resources and energy utilization systems and, ultimately, in the more advanced economies, change in the structure of the economy.

The potential for energy conservation varies greatly between consumption sectors, and the appropriate implementation methods also vary from sector to sector. Examples of such measures are:

For industry:
- Provision of consultation service, especially for small and medium sixed firms.
- Financial and fiscal incentives through grants, loans and subsidies, accelerated depreciation, removal of sales tax, tax write-off, investment tax credits.
- Mandatory energy auditing and reporting schemes.
- Promotion of combined generation of heat and electricity.
- Promotion of the use of low-grade heat from industrial processes for district heating purposes.

For transport:
- Statutory measures to increase vehicle fuel efficiency.
- Advice to drivers on how to buy, drive and maintain cars for reduced petrol consumption.
- Imposition of speed limits.
- Increased petrol taxes.
- Increased registration fees for heavier cars and other with excessive petrol consumption.
- Special taxes on energy-consuming accessories, such as car air conditioners.
- Differential taxation to promote the use of diesel engines in cars.
- Improved urban planning and improvements in public transportation systems.

For buildings:
- Better maintenance of heating systems.
Improved insulation.
- Double or treble glazing.
- Provision of financial and fiscal incentives for energysaving investment.
- Adequate energy pricing.
- Improved building codes.

The Conservation Commission concludes that the conservation potential is much larger in the industrialized countries than in the developing regions. The latter are also likely to place priorities differently and, given the choice, restrict capital investment rather than energy input.

To summarize: There are great successes possible in energy conservation, some of them in the immediate future when they are badly needed. At the same time it is obvious that without vigorous pursuit of energy conservation available energy supply will severely restrain economic growth.

3 NORDIC ENERGY PERSPECTIVES

By this I conclude the summarizing of the report of the Conservation Commission of the World Energy Conference about the global prospects up to the year 2020 and restrict my view to the Nordic countries.

To my knowledge, no study has been made of the energy situation of the Nordic countries as a group that is comparable in scope and time horizon to the one by the Conservation Commission for the world as a whole that I have described here. Therefore I shall not be able to discuss the Nordic situation in the same terms as above. Instead, I shall limit the discussion to the main deviations of the Nordic outlook from the world outlook.

The Nordic countries all belong to the OECD region. In lack of a more detailed information, therefore, we may as a first approximation, assume the energy demand in these countries as a group to grow at approximately the same rate as for the OECD region as a whole, or 1.3% per year on the average, compared to 3% per year for the world as a whole. On the supply side the Nordic region is well endowed with hydraulic resources, petroleum and uranium although the latter may be below world average in economic feasibility. There are also considerable resources of natural gas, but its use within the region is somewhat restricted because of low population density. Economical coal reserves, on the other hand, are severely restricted. One of the countries, Iceland, possesses a large geothermal potential, which however is of little consequence for the region as a whole. Two, viz. Sweden and Finland, have sizable reserves of a lowgrade fossil fuel, peat, which may have some signficance for these two countries. Norway possesses considerable petroleum reserves, uranium is found in Sweden and Greenland. Danmark has some gas reserves. All the Nordic countries possess substantial amounts of non-conventional renewable resources, especially wind and wave energy, presently of a doubtful economic value, however.

It has sometimes been stated that the Nordic countries as a group could be self-sufficient in energy - or at least close to self-sufficiency - for a long time. I do not have data at hand to prove or disprove that statement. But even if it is true it does not mean that there will be no import of energy to the region. Even if there are sufficient reserves of oil and gas in the Danish and Norwegion sectors of the North Sea to supply all thermal electric power stations in the Nordic countries these fuels would not be used for that purpose. The Nordic countries, like any other group of countries, are an integral part of the world. If it is true for the world as a whole that petroleum must be reserved for premium uses like transport and chemical industries, then it is just as true for the Nordic countries. Oil is then simply to valuable to be used as a power station fuel. It then commands a price that would make it too expensive for such a use. Accordingly, oil would be exported from the Nordic region and some cheaper fuels, probably coal or uranium, imported instead for use in power stations.

There is a heated debate going on in the Nordic countries, especially Sweden and Denmark, about nuclear energy. While for the world as a whole there is no question about the necessity to use nuclear fission energy for at least some decades if the economic growth rate envisioned in the Conservation Commission's study is to be realized, individual areas, like the Nordic region enjoy a greater freedom of choice and flexibility. For instance the Nordic countries may totally renounce the use of nuclear energy and use a corresponding greater amount of coal instead for generation of electricity. Assuming that the role of each for the world as a whole is fixed, as previously described, such a choice by the Nordic countries simply means that somebody else has to use correspondingly more nuclear. Such a shift may or may not be possible depending on a number of factors, among them public acceptability of nuclear power in different countries. Some countries may find it more acceptable than Sweden and Danmark, for instance, in which case the shift should be possible. Quite another matter is, however, that coal is not problem-free either.

As to conservation the position of the Nordic countries should be very much the same as that of other developed countries. The need to vigorously pursuit conservation appears just the same as elsewhere. Of course there may be regional and local differences in emphasis.

For instance, in Iceland, looking beyond the next few years, energy conservation is probably more important in fishing and transportation which use imported oil than in space heating, which by then will be almost wholly supplied by hydro and geothermal. This may not be true elsewhere in the Nordic region where conservation in space heating may be very important. As noted, the need to conserve petroleum for premium use is just the same as in the world as a whole so that efforts to achieve that are just as important there as elsewhere, irrespective of the North Sea reserves.

4 CONCLUDING REMARKS

To conclude: The Conservation Commission of the World Energy Conference has recently completed a survey of a pioneering nature of the world energy situation during the next four decades, up to the year 2020. This survey shows that while on the whole there are more than sufficient energy sources in the world to meet the anticipated demand necessary for a reasonable rate of economic growth in both the developed and developing part of the world, the resources of petroleum and natural gas will not be able to sustain a growth in use of these fuels at the same rate as in the recent past, so that a transition has to take place to other more abundant resources, while limiting petroleum use to the socalled premium uses, transportation and chemical industries. For the next few decades this transition has to be primarily to coal and nuclear, while for the more distant future a number of new vistas present themselves. In the long run, man's energy future looks bright, but the transition period may be critical, not because of lack of energy resources but primarily because it may be difficult to affect the transition in the short time available. The main lmitations are men, money and materials. Only through vigorous efforts at energy conservation, prudence, foresight, careful planning and effective international cooperation is there a hope to steer safely through the foul seas ahead. But there is a hope and it is up to us all to help to realize it.