# COMMISSION OF THE EUROPEAN COMMUNITIES

SEC(74) 2592 final/Annex I

Brussels, 17 july 1974

ENERGY FOR EUROPE

RESEARCH AND DEVELOPMENT

Brussels, March 7th, 1974

EUROPEAN COMMITTEE FOR RESEARCH AND DEVELOPMENT

( C E R D )

ENERGY SUBGROUP

# "AN INITIAL ENERGY R & D PROGRAMME FOR THE EUROPEAN COMMUNITY"

## AN INTERIM REPORT TO THE E.C. COMMISSION

presented by

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This document contains general policy considerations as well as technical details. To assist the reader particularly interested in general policy sections, these are marked by a full line on the side.

## SUMMARY OF THE CONCLUSIONS

In this brief interim report we have started an analysis of the energy consumption in Europe and on the world scale, the demand trends and the major problems existing in satisfying this demand. We have emphasized the dramatic situation of Europe which, contrary to the USA and USSR, is presently heavily dependent on oil imported from the Middle East, and the tremendous risk of the situation for the maintenance of the position of Europe in the world, both from the economic aspects and possible interruption of deliveries.

We have indicated the need to substitute as soon as possible the oil with other energy sources and preserve it for the uses where it is still essential.

We have indicated some alternative sources, and we have listed the aspects we suggest for consideration of a major R & D effort.

We have indicated the different energy scenarios which can be projected toward the future, their problems, and stressed the fact that they are options. We have stated the need for a European strategy on energy and the need to create a scenario for the year 2000 as a guideline for the decisions on priorities.

We have stated that the main objective of the R & D effort is the creation of alternatives and of redundancy in the system to provide the flexibility essential for the control of the future energy situation.

We have also stated that it is essential to make the right choices and that this is possible only with the penetrating use of technology assessment techniques and with the use of the techniques for the studies of complex systems. We have stated that the Community Institutions must make recommendations to the Member Countries and promote and direct their efforts. We have emphasized the interim nature of this report, and that the proposals we have made for R & D funding are directed to some specific projects, for which the importance is already well established, and for the deeper study of all the other projects.

When the work of the sub-group will be completed, a final report will be prepared, which will include a complete list of proposals embracing all the aspects of the energy field, including electricity production by nuclear energy which has been specifically excluded from the proposals of this report, since a sizable effort by the Community already exists in the field.

The specific aim of this report is to permit a start at a political level in discussion of the R & D problem, to give the Commission the possibility of mobilizing all the excerts and all the forces which can give a contribution to alleviate the European situation in energy, and to start a constructive dialogue with the other major industrial countries in the world.

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## INTRODUCTORY REMARKS

This report responds to the urgent request from the Commissioner Dahrendorf to present, as soon as possible, recommendations for launching of R & D to reduce the extension of the energy crisis on the European Community.

It is produced midway in the major ongoing effort by the sub-group to propose to the Commission comprehensive integrated energy projects for the short, medium and long term. The intention of the sub-group is to evaluate for each project : the impact; likelihood of success; a PERT for action with identification of the nodal points; and the timing and precise proposals for funding. Further, to suggest to the Commission : ways of the project's best execution; the allocation of effort between research institutes and industry; the development and construction of prototypes in specific types of industry or consortia of industries; and, if know-how is probably better acquired from outside the Community or wider scale cooperation is to be advocated. Each project has to be examined with the methodology of technology assessment and the various alternatives compared with the techniques of complex systems.

The sub-group has been working at full speed, assisted by a number of experts (+) and with the enthusiastic cooperation of the Commission staff guided by its Director-General Dr. Schuster, when the request was made immediately to produce proposals for submission to the Council of Ministers.

(+) See list of sub-group members and experts in the appendix A.

The political reasons behind this request are fully understood by the sub-group. So, despite their reluctance to produce a document at such an early stage, the sub-group presents this interim report. Its objective is to ease and speed political discussion and mobilization of the total scientific, technical and industrial forces available in Europe, and achieve close cooperation in establishing the integrated objectives and strategies of Member Countries.

These provisional recommendations concern only the immediate actions.

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## I. THE WORLD ENERGY SITUATION

Historically, energy sources have characterized social development. Wood was the source in pre-industrial times; coal provided the energy for the first industrialization in Europe, and the ready availability of oil was the major factor in the rapid expansion of industrial development in the U.S.A. from the beginning of this century.

Energy demand in the industrialized countries began to grow very rapidly after World War II. Energy consumption became an index of the standard of living, and correlated positively with the comparison between income *per capita* even if in the U.S.A. the relationship began to be slightly modified.

The demand projections for the next 30-50 years are subject to debate between forecasters, and results diverge. A study of the alternative projections will be a part of the final report of this sub-group and we limit ourselves at this stage to a presentation from a British report of extreme estimates (Diagram 1). The factor which can significantly influence these projections is the scale of growth in underdeveloped, developing and not-yet-industrialized countries. Their populations at the end of the century will be many times greater (say 5 billions) than that of the industrialized countries (say 1.5 billion) in which energy consumption is concentrated.

Energy demand in the world will continue to rise without question, even if better use of energy may reduce the rate of increase, a factor discussed later in this report. The return to a pastoral society dreamed by some poets is most unrealistic. The poorer people strive to achieve the standard of living of the richer, which means individual transportation, more electro-domestic equipment, air-conditioning, more travelling and more consumer-durables, all of which require consumption of energy.

As an indicator of the growth of demand, we can take that the doubling time in the industrialized countries is between 15-20 years. This will be de-creased hen the energy demand by the developing countries begins to repre-sent a larger proportion, and one can easily foresee at least a trebling of the 1973 demand by the year 2000. The huge growth of demand for energy has been covered up to now by using oil as primary energy (electricity is considered as primary energy only when produced by hydraulic power) - up to the present 40 % of the total world energy production. In the industrialized countries, the percentage is much higher. This has been the result of the discovery, a few decades ago of the biggest world oil reserves in the Middle East, exploitable at very low prices. The very convenient characteristics of oil and its adaptability to diversified uses have given to the world a most useful source of energy, and its success is easily understood. The main competitor to oil, coal, became generally obsolete and uneconomic, because it is more difficult to extract, to transport, and too often is more polluting. As a result little has been invested in most of the coal industry, production has rapidly diminished, and in some regions it has only been maintained by governments to alleviate social problems.

Even the introduction of nuclear power, which in the 50s was expected to become rapidly the primary energy source for the future, was considerably slowed down by the low price of oil, to such an extent that nuclear energy represents still only 2 % of the total world energy source.

Oil's supremacy was unfortunately linked to an uneven geographical distri-bution with the major reserves in a part of the world which was underpopu-lated and underdeveloped and with a high degree of political instability.

The continuous growth of demand, the limited life of the oil reserves which at the present rate of growing demand will be depleted in 30-40 years, the dollar devaluation which motivated the producing countries to strenghten their united front within OPEC, and the dominating position of the supranational oil companies, have all been factors behind the present situation; the recent Middle East War being only the occasion for materialising an already predictable event.

The substantial price increase for oil, fixed on 1 January 1974 at (posted) $ 12 per barrel (actual price : 7-9 $ per barrel) is creating a major financial, economic and political crisis in the industrialized world. The annual $ 30 billion oil bill of 2 years ago has risen to well over $ 60 billion, mostly for Europe.

It is not for this report to analyze the political or economic aspects of the crisis, but we are interested in considering the impact of price level on the energy scenario. Unfortunately oil prices are difficult to predict, and the costs of gas, coal and uranium have all started to escalate.

As a result of this rapidly changing situation, a complete reappraisal has to be made of the economics of all possible energy sources and of the effort required for their establishment.

Even if it is clear that oil cannot be replaced immediately and that the tremendous financial burden on industrialized countries has to be alleviated by a political means, by commercial agreements with the producing countries and by the supply of know-how or package deals for development, it is nevertheless imperative to replace oil as quickly as possible and to limit its use to those applications where it is not replaceable, at least in the short-term, for example in air and surface transportation. In any case the substitution decision was inevitable, irrespective of the price of oil, because it is our duty to stop burning hydrocarbons which are a basic feedstock for the chemical industry.

The conservation of energy is of paramount importance and is the other side of the coin. Savings of 10 % in the short term seem feasible and with growing public acceptance regular marginal savings will accrue. Design improvements in buildings and in town planning to save energy will have a large role to play.

The present crisis has made everybody conscious, for the first time, of the need for a long term energy policy. Energy is a major basic ingredient for development of society and for the achievement of balanced wealth in the world. The possession of energy is not only an economical factor, but also a political weapon which has been amply demonstrated by recent events.

THE EUROPEAN SITUATION

The European Community (of the Six) situation on energy sources prior to crisis is summarized in diagram 2 which shows indigenous and imported materials and projections to 1985. This is extracted from an end 1972 Commission report. The average oil dependency for Europe is 64 % but the situation is even more dramatic in some member countries (+): Denmark 99.6 %, Belgium 82,8 %, Ireland and Italy 81 %.

Two major industrial powers, namely the USSR and USA, are in a much better energy situation. The former is a net exporter of energy and the latter imports but a few percent of its total demand and in addition has enormous, easily and rapidly exploitable reserves. For example, oil from Alaska will in 1978 be able to replace half the present oil imports, and there are large reserves of easily extractable coal. In addition, in USA, President Nixon has proposed a major R & D effort to achieve in 5-10 years complete energy independence, even allowing for future increase demand, with indigeneous sources.

Japan, in a very difficult energy situation, importing most of its demand, has already begun a major R & D effort. This is likely to be successful, as Japan has proved in the past its exceptional determination to pursue national strategies and its Government has underlined the ability to orient and mobilize industry and financial resources toward national objectives.

Europe faces the extremely dangerous possibility of its industry having to pay for energy a price considerably higher that paid by its main competitors.

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(+) Industrie et Société, N° 2/74, 15.1.74, p. 2

The loss of industrial conpetitiveness may begin the decline of Europe's world position.

The present 64 % energy importation dependance is dramatic but if we look closer at the medium-term position, there are possibilities for improvement, but only if a major R & D effort is started immedately and major investments are made at the right moment and in the right directions.

The natural resources of the Community in minerals and energy sources are insufficiently known and mapped. Large scale geological on a comprehensive basis is essential to give a realistic inventory on which the options for development can be soundly based, and opportune policies evaluated.

The need for a European strategy in the medium and long term, coordinated and integrated with the efforts of other industrialized countries, will appear as an "absolute must". The three main sources in the medium term are oil and gas from the North Sea, coal and nuclear energy.

The first strategic decision by the Community has to be made on the rate of recommended exploitation of North Sea oil and gas which can give an important and reasonably early contribution to European energy demand if the reserves are as large as estimated by some experts. There is some disagreement on the size of the reserves but an optimistic estimate is shown in Diagram 3, taken with kind permission by Professor ODELL from a forthcoming publication. In figures, 10,000 billion $Nm^3$ of natural gas reserves could be developed by 1980 as well as oil reserves of the order of 100 billion barrels (approximately 20 years of the present consumption rate).

However, disagreements exist on the timing of possible extensive exploitation, on the investments cost, in any case enormously higher than for ground fields, and on the technical difficulties caused by a sea subject to dangerous gales and wave conditions. Of supreme importance is the availability of natural gas which has already completely changed the energy picture of the Netherlands and is having a large effect on the United Kingdom. In the future this will significantly affect the total European gas picture.

Coal is the next energy source in relative abundance in Europe, and here the bottleneck is in extraction. The known reserves are deep and there are difficult problems in recruiting and retaining the necessary manpower. Therefore the increase of the coal availability in the next future depends essentially on basic improvements of the extraction techniques, for which a R & D effort is of main importance.

Europe possesses know-how on benefaction of coal and R & D has a significant supporting role to play. The gasification of coal and lignite and the production of SNG can also create a very valid alternative at the time when natural gas reserves are exhausted. The exploitation of the emerging and significant technical leadership in this field can be a significant bargaining counter in discussion with other countries which are perhaps more advanced in different techniques.

Nuclear energy is essential to fill a power gap in the medium term and is the only additional source of primary energy available to Europe that is likely to make a large impact in the longer term. The question of dependence on imported uranium and its enriched derivatives is not yet completely solved for the Community.

Of the newer sources of energy, geothermal has a large potential, particularly in some parts of Europe where probably "dry hot rocks" suitable for industrial exploitation already exist. An urgent R & D effort is required.

Solar energy is immediately exploitable for local small scale application particularly in Southern and Central Europe, but the impact on the total energy picture will be limited, unless large scale equipment for electricity production becomes available.

Thermonuclear fusion would in principle provide a practically inexhaustible supply of clean and inherently safe energy; however owing to the present level of development, thermonuclear fusion is not expected to be available for on-line power production before the 2000s. The present R & D effort however must be maintained and, where necessary, accelerated.

A major R & D European effort on new sources is imperative. The main object is to create alternatives to imported oil and to provide a margin within the energy system. This is critical for strengthening the European position in overcoming instabilities in energy supply.

The required R & D effort and the related industrial exploitation are certainly wasteful and might prove to be insufficient unless a vigorous coordination action, based on a common strategy of European countries, is carried out. The result of creating a common european R & D effort and establishing a common policy and strategy for Europe, at short, medium and long term, would permit to bring to the break-even point energy sources other than the low-price oil we have enjoyed for 20 years.

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## . CONVENTIONAL ENERGY SOURCES AND SUBSTITUTION POSSIBILITIES

Chapters II and III are the summary of a "tour d'horizon" that the Subgroup undertook before starting with the deep and detailed analysis of each subject. Therefore no one of the topics here given was exhaustively examined and their relative importances were neither considered nor established. The Subgroup however estimates that the present considerations give a picture of the many problems to be solved and of the possible measures to be taken and that they are an useful guideline for the work the Subgroup must carry out from now on.

### A. ECONOMIZATION AND CONSERVATION OF ENERGY

The objective here is to use energy more efficiently and to reduce losses. In the Community the losses account for about two thirds (67 %) of the total available energy. About one third (35 %) of these losses are in production and conversion processes, 3 % in distribution while the rest is in final utilization: household (26 %), transportation (17 %) and industry (19 %). If the losses are related to the consumption of each of these final utilization sectors they may be evaluated ar more than 80 % in transportation, about 60 % in electricity production, somewhat more than half in the household and somewhat less than half in manufacturing industry.

Besides these technical losses there are considerable losses by wasteful applications.

Savings can be made by :

- technical improvement, including rearrangement of production factors;
- overall optimization of the energy systems;
- reasonable changes in life style.

The rules of the market economy forces play a role in the search for energy savings. However, a fast and coherent change of long-term significance cannot be entirely left to these forces; it also needs a R & D effort, and a degree of public policy.

It will be necessary for instance to consider :

- the elaboration and enforcement of norms on the thermal insulation of buildings, on the efficiency of domestic, commercial or industrial equipment;
- recycling materials, including waste recovery;
- development of more energy efficient transportation systems;
- transsectorial optimization in order to achieve a better overall efficiency.

These and similar considerations need to be inserted into a global system approach including numerous economic and social factors, among them life style and motivational structures. Such a global vision should also open the way to an antiwaste morale essential to success of an energy conservation policy.

Possible impact

Opinions differ widely as to the possible effect of savings and better use of energy. Energy requirements reduced by 10 % under the level otherwise to be reached, would be a possible goal in a couple of years. In the longer run an appropriate effort would allow a gain of some 2 % a year at least for some time.

Research objectives

Within R & D the problems are not purely technical, and the following subjects can be considered :

- analysis of the interactions among the components of the Community's energy systems, in order to determine the more efficient combination of fuel supplies, energy transformation and uses;
- elaboration, demonstration and industrial realization of energetically optimized urban systems, including transportation of goods and people;

- elaboration, demonstration and industrial realization of energy optimized housings;
- development of more energy efficient engines for stationary or mobile conversion systems (improved internal combustion engines, Stirling engines, electric motors for cars with batteries, fuel-cells or other sources of power);
- gas turbine-boiler combination and other topping systems if preliminary studies show that they have a worthwile net effect;
- possible uses of lower-end-heat of power plants;
- reduction of losses in power transmission and distribution networks;
- recycling processes for metals, plastic and glass;
- recuperation of energy from organic wastes;
- redesigning of some industrial processes (energy optimization).

B. INCREASE OF INDIGENOUS SUPPLY OF OIL AND GAS

The main objective is to speed up the exploration and discovery of the resources of oil and gas available inside the Community or in reliably accessible areas.

This could be achieved by improving :

- the knowledge of the inventory of the Community resources;
- increasing the exploration and assessment of the reserves;
- the methods for the recovery from the known reserves.

In view of the problems related to catastrophic spillage during offshore drilling and the legitimate public resistance after a catastrophy special R & D efforts are required to assure the maximum possible safety and the most efficient intervention techniques in case of spillage.

Research objectives

a) Improvement of the knowledge of the inventory of the Community resources:

An improvement of the knowledge of the availability, distribution, basic properties of the overall natural resources of the Community, especially of reservoirs of gas and oil will considerably decrease the financial risk of exploration and development.

It is necessary to develop :

- theories of natural resources formation and distribution;
- methods for making qualitative estimates of the size, location nature and properties of resources;
- methods for assessment and accurate inventory of resources by direct measurement of element distribution and content.

b) Improvement and increase of exploration and development methods:

The exploration and development phases are very costly and commercial firms will only drill when the probability of success is high, leaving aside sites with possibly non negligible reserves.

Only a systematic exploration coupled with a systematic assessment of the results could ascertain that no major reserves have been forgotten. The risk entailed by such an operation should be shared and coupled with public incentives to exploration. In the short term favorable legislation and financial or fiscal incentives may be suitable but in the long run new techniques and technology for exploration and development will have to be developed.

Deep-sea drilling, between 200 m and 3.000 m which covers the Mediterranean, brings a new dimension to the problem already solved for the continental shelf and requires development of :

- positioning techniques for drilling craft and bore-hole-reentry;
- remote observation and operation underwater;
- new wellhead equipment and new methods for maintenance;
- new drilling techniques;
- new storage facilities;
- deep-sea pipelines.

c) <u>Improvement of secondary and tertiary recovery</u>

About 70 % of the oil reserve is left in the ground, thus any technique for recovery of part of this increases potential reserves. The less well known include solvent injection and <u>in situ</u> combustion.

Research is recommended on internal structures, porosity and permeability of reservoirs, on solvent and on underground combustion recovery, and as the possibility of reenergizing gas reservoirs by explosions.

## C. SUBSTITUTION OF OIL BY OTHER ENERGY RESOURCES

The goal of all R & D is to increase the possibilities of recourse to primary energy which is more secure and presents a larger and safer geo-political supply basis than natural petroleum. These are, in terms of immediate availability : coal and lignite and uranium and thorium.

### 1. Coal and lignite

The use of indigenous coal in the European Community has stagnated, in absolute terms, and considerably decreased relatively, during the last decade. This has been, on the one hand because the availability of cheap imported oil and on the other hand the convenience and flexibility of liquid and gaseous fuels. Imported coal, mainly from the USA and Poland has taken some of the market. An increased importance of coal in the overall energy supply therefore would be assisted by :

a) an increase and rationalization of indigenous production; this covers:

- exploration and assessment of new coal reserves;
- further improvement of the existing mining techniques;
- automation of underground operation;
- systematic and joint industrial assessment of the advanced mining techniques being developed in Belgium, France, Germany, U.K..

b) an improvement of the efficiency and convenience of the direct uses of coal.

Here the key areas are :

- high efficiency combined cycle power plants (gasification/ gas turbine/ steam boilers/ steam turbines) with the possibility of desulphurization by $H_2S$ removal; desulphurization techniques, including stack gas desulphurization, to allow use of high sulphur imported coal (and allow flexibility of fueling);
- topping and/or bottoming cycles added to coal fired power plants;
- solvent extraction and/or pyrolysis of coal in order to furnish industrial, commercial and even private consumers with an ashfree, sulphur-free and easily storable fuel and/or feedstock for petrochemistry.

  A demonstration programme, that could be coordinated with similar work in the USA and Japan with exchange of complementary experiences and preferential licensing conditions, is suggested on :

- a fluidized combustion plant with desulphurization.

  Fluidized combustion has been developed on a small scale in U.K. and needs to be demonstrated on a scale of about 20 MW to demonstrate that capital costs savings can be achieved together with higher overall generating efficiency and the avoidance of sulphur emissions. The elegant desulphurization and the reduced waste product disposal problems seem to offer cost advantages over stack gas desulphurization.

- 1 or 2 stack gas desulphurization processes fully integrated with a power plant and including the waste disposal (or by-product) stage.

  Plant sizes should be at least 150 MWe.

- two combined cycle-gasturbine/steam turbine-power plants of at least 150 MW(e) with different approaches to systems integration and with different advanced gasification processes (e.g. "slagging" variant of Lurgi process, pressurized Koppers-Totzek process, or similar processes);

- pilot programme possibility within a Community/USA framework of :
  - 2 pyrolysis units of different characteristics
  - 2 solvent extraction units, one of which with supercritical gas solvent.

  Coal throughputs at least 10 t/h.

  The demonstration programme must be integrated by an assessment study, based on the available knowledge, of topping and bottoming cycles which might be added to fossil fired power plants.

c) The transformation of coal into other energy sectors (gases, liquids) which lend themselves to easy substitution of natural hydrocarbons and their derivatives. Major aspects are large scale production of Clean Fuel Gas (CFG), Substitute Natural Gas (SNG) and synthesis gas from the largest possible range of coal and lignites.

   Specific projects recommended are :

   - one year assessment study of the different lines pursued in the U.K. and Germany on fluidized bed type synthesis gas production plants. To be followed by a feasibility study and a joint demonstration programme (2-4 plants, at least one of which in the Community preferably with integrated stages for SNG and methanol production; at least 500.000 t/y coal throughput).
   - industrial size methane producing hydrogasification plant on lignite basis (pressurized fluidized bed of German or U.K. technology, 100.000 t/y lignite throughput).
   - synthetic crude oil demonstration plant of about 500.000 t/y coal throughput in possible collaboration with USA by experience and licence exchange.

   It should be well understood that all proposals, plant types and sizes are purely indicative and should be reviewed by specialist teams; in particular in the framework of ECSC. It is also possible, in some case even very advisable to combine several different plant units and programme items in one complex, such as solvent extraction with gasification and with fluidized combustion for electricity production.

It is highly desirable that in parallel with the R & D areas abovementioned under a), b) and c) a suitable modeling effort could be undertaken for the fossil fuel system as a whole (production, transport, storage, transformation, uses) including oil refinery, petrochemistry, electricity production, coal gasification and liquefaction, also the options of desulphurization stages. The model might even include regional, siting, trade and monetary aspects. It should permit an assessment of the real merits of industrial processes and strategic options in the framework of the Communities overall industrial economy.

A comprehensive programme of collaboration with partners outside the Community will need to take into account suggestions made above and in other sections of this report.

## 2. Nuclear fission reactors for electricity generation

Proven reactors (light Water Reactors (LWR), Heavy Water Reactors (HWR) and Gas-Graphite Reactors (GGR)) are the only presently available technological alternative to conventional methods for electric power production. With the exception of Canada and maybe Great Britain, all the industrialized nations have decided on cost basis that the first commercial nuclear power would be based on LWRs. These need enriched uranium fuelling which implies presently that 3% of the electricity generated has to be used for this enrichment on the basis of the only technology available today for mass production, i.e. membrane diffusion. Ultracentrifugation, the large scale commercialisation of which is planned from 1980 on will reduce electricity requirements by a factor of about 10. Other exotic schemes for uranium enrichment which might result in even better efficiencies are also being explored.

If uranium enrichment had to be avoided, the only other reasonable alternative existing today would be HWRs which are cheaper than GGRs. Such a reconsideration of large scale introduction of HWRs is nevertheless highly unlikely in those countries which have selected LWRs because of the present orientation of their industrial structures, and because it would necessitate large heavy water production capacities being built.

For the other reactor lines, it can be envisaged that :

- High Temperature Reactors (HTR) could contribute to electricity production around 1980, on the basis of the experience of the Fort-St-Vrain (USA) and Schmehausen (Germany) prototypes to be started up respectively in 1974 and 1977. Compared to LWRs, this reactor type offers the potential advantages of a better intrinsic safety, higher temperatures usable for improved steam cycle efficiency, closed gas turbines thereby easing the siting and thermal discharges to water or heat for industrial processes, as well as a possible use of the earth's abundant thorium reserves.

- Liquid Metal Fast Breeder Reactors (LMFBR) could be commercially available around 1985-1990 on the basis of the Phonix (France), PFR (UK), SNR (Germany) and Clinch River (USA) prototypes, the dates of criticality of which are respectively 1973, 1974-75, 1978-79 and 1980. This reactor type could ultimately give complete independence from enriched uranium sources by making use of the plutonium produced by the preceding "converter" reactors, and of the large amounts of depleted uranium stockpiles which will be available at the time of their commercialisation. An independence date from enriched uranium before 2000 or 2010 would nevertheless be impossible, because of the necessary long timing of commercial introduction of these types of reactors. It is furthermore tied to minimising as much as possible the doubling time of the fissile material inventory which implies development of advanced fuels such as carbides rather than the present prototypes fuel, i.e. oxides.
- Gas Cooled Fast Reactors (GCFR) might become commercially available from 1990 on, by combining the experience and hopefully the advantages acquired earlier with both HTRs and LMFBRs.
- Even though small efforts are still being devoted in the USA and in the Community to other reactor lines, i.e. thorium LWR and Molten Salt Breeder Reactors, their potential is questioned, in particular in view of the formidable technological problems they raise.

Necessary R & D effort

The recourse to nuclear reactors for electricity production can only increase. For the Community 8% of electricity (22 GW) will be from nuclear power in 1975, raising to 14% (55GW) in 1980. Projections to 1990 and 2000 were for 40% and 80%. The implications of these projected installed capacities must be carefully examined.

Several strategies can be and are being envisaged in cost-benefit analyses for the different reactor types cited above, but no single optimum can prevail in absolute terms, in particular because of the many factors to consider, such as access to uranium and thorium resources, availability of industrial capacity, capital financing, suitable reactor sitings, severeness of safety regulations, and acceptance by the public of nuclear energy.

Further studies and experimental work are necessary on the following subjects :

- transportation and disposal of radioactive wastes;
- effects of ionizing radiations on living matter and radioactive contamination of the environment;
- safety of LWRs;
- HTR, LMFBR and later GCFR developments (including their safety aspects);
- radioactive product retention in the LWR reprocessing cycle;
- development of reprocessing methods for HFRs and LMFBRs;
- ultimate decommissioning of nuclear plants.

Nuclear reactor exploitation raises additional questions deserving further studies :

- availability of uranium and thorium resources;
- siting problems associated with the possible thermal discharges and radioactive release. The first aspect may be solved by offshore plants, the second issue might lead to the "nuclear parks" concept where very large reactors units would be located, possibly with their reprocessing plants. This in turn raises the question of energy transportation from such parks to consumption areas with possible use of supraconducting cables and gases;

- transportation problems of both fresh and irradiated fuel;
- optimum use of the generating electrical capacity : possible production of electrolytic hydrogen by off-peak power, to be either burned in situ during peaking hours or sent to chemical or metallurgical industries.

## 3. Non electrical use of nuclear reactors

Objectivesare : substitution by nuclear heat of fossil fuels used for process heating; stretching of fossil resources by transforming the fuel into compound energy carriers produced by endothermic reactions in which the energy input is furnished by nuclear sources; this may also render the output compounds energetically cheaper than the fossil inputs, if nuclear heat is offered advantageously; production of secondary energy vectors other than electricity, in particular by water splitting and substitution of oil by nuclear energy for the propulsion of large merchant ships.

### a) Process heat for industry

Classical process heat consumers are widely scattered and of unit sizes uninteresting for nuclear reactors, with 2 exceptions : the chemical industry and the metallurgical industry.

Of the 35 % of total primary energy consumption by industry, chemical industry consumes more than 2/5. About 40 % of this is raw material for syntheses, the remaining 60 % are used for process and auxiliary heating. If one takes only the large industrial complexes, then roughly 5 % of primary energy consumption of the Community could theoretically be substituted by process heat nuclear reactors in chemical industry. More than 90 % of the consumption of heat is in the temperature range between 120° C and 210° C and uses steam as a heat carrier so that all reactor types could be used. No particular research is needed, beside increasing general plant safety to permit siting of the reactors near industrial centres.

Metallurgical industry on the other hand consumes most of its energy at temperatures above 600° C, mostly above 900° C. High temperature reactors could serve, as a heat source for producing reduction gas for direct reductions plants, and for making reforming gas to inject into blast furnaces to reduce coke consumption (by some 30-40 %). Gas production for this purpose is not fundamentally different from that dealt with below.
It is suggested that the known direct reduction processes should be further developed, in particular for hydrogen and hydrogen-containing gases as reduction agents.

A reaction heat closed cycle gas system as proposed in the Federal Republic of Germany could serve the consumers of heat less concentrated than the chemical and siderurgical industries and in particular provide the large scale low temperature heat for domestic use.

Central point for this technology as well as for those given below is the availability of a high temperature process heat reactor which at present is only a conceptual design stage.

Research proposals

- Detailed design and associated R & D work for process heat HTR pilot plant (to be followed at the end of the seventies by a realization);

- Systems analysis of the reaction heat closed cycle gas system.

b) Stretching of fossil fuels

Reforming of methane, reforming of naphtha, hydrocracking of heavier oil fractions, hydrogasification of coal, including the necessary hydrogen production and coal gasification with steam, are endothermic processes, in which up to 40 % of the energy content of the output products may in principle be supplied from an external heat source. The respective fossil fuels may thus be "stretched". It has been suggested that the external source could be a high-temperature reactor but the necessary R & D is large especially for the steam-coal process which needs temperatures in excess of 1000° C, i.e. temperatures of above 1200° C in the reactor core. Hydrogasification of coal may be of interest if it can be established that substantially all the coal can be gasified in this way, lignite is cheaper and more reactive and needs lower process temperatures.

Research proposals

Methane reforming is standard industrial practice and its adaptation to nuclear heat mainly concerns heat exchanger development. Hydrogasification plants exist in small pilot scale. The promotion versus the industrial scale of autothermal gasification process is treated in C. 1.

Independently of the development of large size and high helium outlet temperatures HTR's (950-1000° C in the medium term) the following actions have to be undertaken :

- Development and testing of heat enchangers of different promising designs and pipework for transmission of heat from Helium to methane/cracked gas, hydriding gas circuits, at temperatures up to 1.000° C, pressures of about 60 at. and unit rates of 500 MWth and more.

- Safety and reliability analyses of different types of chemo-industrial complexes with nuclear reactors.

c) Hydrogen energy system

Hydrogen economy

Hydrogen is not an alternative primary energy source but it is a general purpose secondary fuel which can be produced by electrolysis, processing of fossil fuels, or thermochemical decomposition of water.

Hydrogen is, compared with electricity, cheaply transportable, through pipeline in gaseous or liquid form, storable and non polluting.

In a Hydrogen Energy System, almost the whole energy market may be covered by hydrogen.

Main potential uses are :

a) basic chemistry : Ammonia, methanol and other syntheses;

b) refinery processes : hydrosulphurization, hydrocracking and hydrotreating;

c) metallurgical industry : replacement of coke in the reductien of iron ore for steel making;

d) industrial heating : alternative to fossil fuels;

e) residential : domestic heating (catalytic burners), fuel cells for electricity production in isolated areas;

f) transportation : hydrogen fueled ground vehicles with contribution to pollution abatement and aircraft with their high premium on weight;

g) local power generation : for energy delivery at distances over 500 km, hydrogen is economically more advantageous than electricity.

In a "Hydrogen Energy System" the by-product oxygen could be used in combustion processes, in sewage treatment, waste disposal, and steel refining. Some research topics are :

- Theoretical study, experimental research and pilot scale testing of hydrogen transportation, distribution and storage devices and systems, including aspects of compatibility and adaptability of natural gas pipelines, with research on hydrogen embrittlement of metals at high pressure;

- assessment of hydrogen fueled ground transportation vehicles and aircrafts, followed by realization of one pilot project for each category;

- preparation of a European safety manual.

Paraconventional hydrogen production

Up to now hydrogen is mainly produced by methane reforming followed by a shifting process. Lesser amounts are also produced by coal gasification with steam, and by electrolysis. By the introduction of advanced gasification processes and in particular with the coupling of HTRs to methane reforming and/or gasification processes it will be possible to decrease hydrogen production cost and hence widen its market. Of particular importance may become the possibility of using the cheap-off-peak-power for electrolytic hydrogen production. This would however require development of electrolysers several orders of magnitude more powerful than those now available in particular those of higher power density and of high efficiency, 80 % or more compared to the present 60 %.

Thermochemical decomposition of water

It is theoretically possible to split water, without the detour and efficiency loss of electricity production and electrolysis, by thermal decomposition at very high temperatures, but probably also by a combination of several thermochemical processess, with temperatures as low as 600°C (the number and the complexity of the processes decreasing with increasing temperature). The potential heat sources for thermochemical water splitting which have been proposed are:

- High Temperature Reactors (HTRs) with coolant exit temperatures in excess of 900°C;
- The LMFBR's and GCFR's with coolant exit temperatures ranging from 600°C to possibly 800°C.

In the present state of the art it is of paramount importance to prove the technological and economical feasibility of the concept. Once a positive answer to this question is obtained, a massive developmental effort through different pilot and demonstration plants should be undertaken.

Research proposals are:

- investigation of the kinetics of the basic reactions after thermodynamic screening of the possible sets of processes; on corrosion and other material problems given by these reactions; heat transfer studies; chemical engineering studies for the evaluation of technical and economical feasibility of possible process combinations for water splitting; conceptual design (title I) of a full scale integrated hydrogen production plant with an HTR as heat source.

d) Marine propulsion

At present 7% of crude oil consumption is used for ship propulsion. It can be expected that roughly 1/3 of bunker supplies will be used in very large and/or fast vessels by 1990. Nuclear propulsion will present an economical proposition only for such types of vessels.

The technical feasibility of nuclear propulsion has been sufficiently demonstrated by the successful operation of the experimental civilian vessels "Savannah" and "Otto Hahn", the latter having a reactor of modern design. In order to prove that the building of nuclear fleets would be economically justified, the building of an economic demonstration ship would have to be agreed first between the various commercial interests involved. Subject to satisfactory participation of ship owners, and on the basis of a prior analysis of risks and benefits, Community participation would be appropriate.

As a backing-up of this demonstration programme, R-D activities in this field should also be supported which would comprise studies and research concerning collision protection, nuclear safety and infrastructure for maintenance, repairs and fuel supplies.

## D. ENERGY TRANSPORTATION AND STORAGE

### Transportation

a) by electricity

Fuel and energy transportation is more a matter of cost than of efficiency or energy saving.

The most expensive form of energy to transport, which therefore deserves particular attention, is electric power. It is transmitted by high voltage overhead lines, and distributed in towns and populated areas by underground cables.

Transmission involves losses of about 5 % in the European power grids To keep these losses down to this level, the current intensity has to be restricted either by using several transmission lines or by raising the voltage.

Overhead lines offer significant development potential. In Europe, although the 400 kV power grid is considered sufficient for a long time, studies are already underway for voltages of 1000 kV and up. For long-distance transmission direct-current would be preferable to a.c. if the current-conversion equipment were cheaper. No other technology is envisaged now.

The capital cost of a 400 kV overhead line is 15 times less than that of equivalent conventional underground cable. This ratio should increase with increasing voltages. Consequently, underground cables will only be used for transmission in those areas where overhead lines are impractical, namely for the penetration into densely populated areas. These particular situations will require the now being developed high performance cables, forced-cooling cables, polyethylene cables, $SF_6$-cables, cryoresistive cables and supraconducting cables. These new cables have heat losses at least equal to those of overhead lines, for exemple, in cables operating at very low temperatures, cryoresistive cable, to extract 1W of heat from the cable, for cooling and circulating the coolant 10 W is required by the refrigerator. The only truly efficient cable would be the supraconducting cable for direct current: the refrigeration would only have to compensate the leakage of heat into the cable through imperfest thermal insulation. However, there would then be a loss of about 2,5% in the current-conversion stations.

Supraconducting cables both d.c. and a.c. offer good prospects for carrying large amounts of power; perhaps up to 10.000 MVA in one single cable. They will not be commercially available before 1985. Considerable effort in research, development and demonstration is required.

The Commission has undertaken to study the possible market prospects for high-power cables and the techno-economic comparison of the various concepts, in order to know where the R-D empasis would be the most appropriate.

b) by fluids

It is well known that chemical energy carriers such as liquid or gaseous fuels have transportation costs of only one tenth that of electricity. This is e.g. one of the attractive features of a "gas scenario" and systems proposals as well as research proposals pursuing this line are given above.

The cheapest means of transporting fuel, both natural gas and hydrogen, is pipe-lines. Studies to make compatible pipe-line systems for the various types of gas including hydrogen are of great importance and urgency.

Storage

Storage is to be understood not as stock-piling but as a means of increasing the load factor and hence overall efficiency of energy production and in particular electricity generation plants.

Today the only way of storing electric power is by hydro-electric pumping, but its feasibility is limited by the availability of suitable sites. Little progress is exprected in this field and little R-D effort is foreseen.

Energy storage in the form of compressed air in large underground cavities coupled with gas turbines has been proposed and is already in use in Sweden. A careful economic evaluation is necessary before steps are taken towards beyond construction of a prototype plant.

Advanced batteries and accumulators are considered up to now too expensive for large scale applications.

With the increase-percentage of electricity produced by nuclear power plants, the need for storage of energy from electricity will become more and more felt, not only because of the higher investment impact on the energy production cost, but also because of the risk of plant and fuel element failures which increase with the frequency and magnitude of load changes.

Hydrogen production appears to be the most convenient means of storing energy from electricity. Excess electric power could be used at periods of low demand to produce hydrogen and oxygen. They would be stored and recombined in fuel cells to produce electricity at peak demand. It must be noted however that efficient and low cost fuel cells are not yet available today and are still a field of a major R-D effort. Extensive use of this technique will probably not be made before the advent of the hydrogen society.

Massive storage of liquid and gaseous energy carriers presents development incentives both in the pursuit of the possibility of gas storage in abandoned mines and in the exhausted natural gas fields.

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## III. NEW NON-CONVENTIONAL ENERGY SOURCES

### A. GEOTHERMAL ENERGY

Geothermal power today currently utilized is based essentially on the exploitation of the dry-steam fields, located in the volcanic regions of the Community (Italy).

Other sources however are available as : wet-steam fields, low-temperature fields and hot dry rocks ; their true extensions are largely unknown and experts estimations vary by orders of magnitude, but their potential can be very high, as hot dry rocks are estimated to be vast, diffuse and available nearly everywhere at sufficient depths.

Their exploitation for electric and non-electric purposes are hot waters and brines for space heating, air conditioning, industrial heat utilization and chemicals (salts and minerals) extraction could lead to a rather large fuel saving.

As present estimations are based generally on the heat recovery at depths ranging from 6000 to 10000 m, it must be noted that more advanced technologies (drilling of very deep fields) could substantially increase the total amount of recoverable thermal energy. Moreover it must be considered that in some cases these resources can be exploited quickly and contribute to the energy saving in the short term, particularly from dry hot rocks without the major problems of corrosive environment associated with near volcanic magmas.

An important goal for the Community could be to exploit the different sources by developing and demonstrating the technolgy that would allow increasing and promoting the commercial production of electric power and other energy uses in the respect of the environmental requirements. Consequently an action leading to a coordinated effort for the comprehensive assessment and potential of European geothermal resources based on extensive mapping and survey, as well as for their industrial exploitation looking for a rapid bringing them to on-line production has to be strongly recommended. Exploitation of rocks, bringing together with steam, corrosive salts may be considered in the light of recovery of by-products.

The main R&D problems are :

- Transfer of the known deep-drilling and hydrofracturing technologies from sedimentary rocks to hard igneous ones.
- Scaling up of dual-fluid cycles at low temperatures.
- Drilling in hot corrosive environment.
- Basic research on gases and solid solubility and corrosion problems in highly concentrated solutions at high temperatures.
- Monitoring and elimination of wastes.

## B. SOLAR ENERGY

### 1. Habitat

Decentralized solar systems for space heating, water heating and air-conditioning in houses and buildings are technically feasible today and some are in pilot-scale. Operating costs are low ; initial capital costs could be kept low if industry were prepared to manufacture heating and cooling systems in large quantities and if improvements are made in the design and fabrication methods of the collector, whose cost is approximately 3/4 of the total. It is expected that 30-50 % of the energy consumption for habitat may be covered eventually by such systems.

The objectives are to improve solar energy collection and storage techniques ; to establish design criteria, to develop and test components ; to build demonstration houses for effective use of solar energy.

The main R&D problems are :

- System studies to evaluate the relative merits of the variety of collectors/storage/cooler/water heater systems.
- Energy storage systems.
- Improved collectors (surfaces, optical properties, materials, increased life and energy yield, manufacture techniques).

2. Electricity production (thermodynamic cycle)

Although feasible, no life-time prognosis can be made of the delicate related items. The high quality devices of elegant design and precious materials ask for intelligent and prudent use and for serious study of providing alternatives of components before constructing power plants. A critical R&D area is on concentrators : design, materials of construction, durability and cost, particularly as a function of optical precision. Other R&D areas are in long heat pipe technology, long heat transfer loops to collect thermal energy from very large concentrators systems, energy storage technology. As operating temperatures as high as 500°C can be obtained, high conversion efficiencies into electricity are expected. Despite the important problems to be solved, it must be mentioned that this type of conversion could potentially satisfy all energy needs. The requirements for small size equipment are not to be underestimated, particularly small power sets of a few kW for Africa and developing countries.

The objectives are : to investigate the operating potential of key sub-systems; to improve the collection, concentration and transmission techniques; to improve energy storage techniques at high temperature.

Main R&D problems :

- Concentrator technology (costs, materials)
- Selective surfaces (life-time and durability)
- Collector and heat transmission technology
- Best thermodynamic cycles and prime movers in different collector configurations

3. Photovoltaic conversion

Silicon cells, with a conversion efficiency of approximately 10 %, and already space-proven are now handicapped by very high price, which must be reduced to one hundredth to be competitive. When mass production reduces the price to a tenth, already a number of energy saving applications can be seen, e.g. battery charging for boats, caravans and cars. For further reduction, the R&D area could cover new methods of silicon cell production and the possible use of organic cells.

The main industrial objective is to produce economically competitive photovoltaic cells on a full plant scale, and to determine the possibility to use present cells in an acceptable economic way (concentration devices).

The main R&D problems are in :
- New production methods for silicon cells
- Use of other inorganic semi-conductors such as cadmium sulphide, gallium arsenide
- Basic studies on organic semi-conductors
- Energy storage systems

### 4. Biological conversion

Through photosynthetic processes designed to maximize energy yields of plant materials, the normal low global efficiency of the order of 0.1 % can be increased to some 3 % or more. Plants can be algae or crops or $C_4$-type (sugar cane or corn). The R&D area includes plant genetics, harvesting technology, growth medium technology, as well as the study of optimal processing of the produced organic materials to transform them in gaseous or liquid fuels by methane fermentation or pyrolysis, etc. The concept for direct formation of hydrogen gas from water, using photosynthetic processes, must be evaluated and tested.

## C. THERMONUCLEAR FUSION

During the last two years, the numerous programmes of thermonuclear fusion in the world have yielded essential progress in magnetic fusion (MCF). Optimistic experts assume that the feasibility of MCF, using Deuterium-Tritium reaction will be demonstrated between 1978-1982, leading to a low power prototype running in the 1990s.

The new methods of laser fusion has equally shown considerable progress, but the development of more powerful lasers is still needed. Investments in money and time required to prove the concept of laser fusion are less known and less predictable, since part of the research is in the military sector.

One can confidently assume that if the experiments planned for MCF are successful, the introduction of large-scale fusion power would take place at the beginning of next century, making it an essential, clean and abundant energy source from that time on.

Necessary R&D

Considerable R&D efforts still have to be made in fusion continuing present efforts, going from basic experiments to the physical feasibility demonstration stage to the engineering feasibility stage followed by the prototype one.

If the feasibility is proved early enough, the R&D efforts lasting at least till the end of this century are estimated to about 5.000 Mua

Practically the whole effort in the next 10 years will be financed by public funds since industrial companies have no incentive to invest in this field because its possible commercialization is only long term.

In the past, research expenditure on MCF has been at the same level of about 50 Mua/year both in the Community and in the USA.

In the USA proposals have been made for a substantial increase for MCF to 1240 Mio dollars for the 5-year period 1975-79.

In order to remain at a comparable scientific and technical level, an increase in the Community"s research programme would seem to be indicated.

Concerning laser fusion, present predictions would be unrealistic in view of the large intervention of the military sector in this field ; let us simply note that the USA foresee R&D civilian expenditures for laser fusion which are 10 % of those for magnetic confinement one.

CERD notes the effort being made in the framework of the Community's Thermonuclear-Fusion Programme and supports expansion of this effort. The successful completion of a programme by 1990 is recognized to have significant effects on global energy strategy.

## IV. THE ALTERNATIVE SCENARIO ELEMENTS

The two preceding parts of this report clearly indicate the possible sources of energy which can be made available in the coming years if the R & D problems are successfully solved.

Theoretically, if each one is fully exploited; at least for a limited period, we can construct the following elements for a scenario :

1. Solid coal
2. Oil (liquid fuel)
3. Natural gas
4. Gasified coal (SNG)
5. Nuclear energy with electricity as the main secondary energy
6. Geothermal
7. Solar energy
8. Nuclear energy with methane ($CH_4$) or hydrogen ($H_2$) as the main secondary energy source
9. Nuclear fusion.

These elements are clearly not entirely alternatives and an intermix will probably give the optimal solution to the different types of energy use, for temporary and local conditions. The following additional indications on the implications of each element will help in understanding their complexity and the choices available.

1. Coal has been, until recently, the basic source of energy and although it could not return to this position, it is likely in the future to continue to play a major role for a considerable time, particularly in the steel industry and in thermal power plants. In the long range, coal could be used to provide hydrocarbons to supplement and replace diminishing oil and gas supplies.

2. The oil element is now used predominantly, in particular for some Community-Member-Countries and for Japan. It is possible that - due to the system's inertia, and in spite of the difficulties - consumption will continue to increase and remain high for many years. The North Sea dis-

inuing oil use.

Nevertheless, as stated, oil reserves are limited and should be preserved for uses where high calorie liquid fuels are the only available solution. This includes aviation and the use as a basic feedstock for many processes of the chemical industry.

3. The natural gas element: In parts of Europe a capillary system of gas distribution is in operation with great success. A major advantage is the elimination of oil distribution by road transport.

   The creation of a complete network in Europe will be eased by the discoveries in the North Sea, importation of gas from Russia, North Africa and possibly even the Middle East. The distribution of gaseous energy has advantages in improved storage capacity, reduced environment impact by underground pipelines and avoidance of storage at the user site.

   The natural gas network can be used for the distribution of SNG or for pure methan, but may require substantial modification to be used for hydrogen. The existence of the gas network however allows a dependence on gas to be considered as an alternative to oil.

   The possibility of producing SNG from oil feedstock is an interesting alternative to the use of liquid fuels in a gas society.

4. Coal gasification. It appears as a most promising option for a medium/long term solution and as a natural continuation of the present expansion of natural gas consumption. The major problems are the extraction of indigenous coal and/or the possibility to insure adequate supply from other continents. Owing to the economy of transportation of solid fuels, when using domestic supplies the gasification plants must be located close to the mines, while some plants would need to be located at coastal sites to allow for the import by sea. The technology is already available, but further R & D at industrial level is required for the development of more efficient plants possibly integrated with power plants.

5. <u>Nuclear energy for the production of electricity</u>. Nuclear energy is now one of the cheapest forms of primary energy, even if the price of uranium has begun to increase. This increase has the effect of making it economical to exploit a larger number of ores, thus dramatically increasing the availability of uranium. If the rapid expansion in the application of nuclear energy reaches 1000 Gigawatt worldwide in year 2000 - already a forecast of some experts -, fast breeders are a must if uranium recovery from seawater proves too expensive. Attention has to be paid to safety, ecology, the disposal of radioactive waste, and technology of the coming reactor generation, particularly the fast breeder. The Amerioan R & D programme for energy gives to the nuclear energy sector the title "How to validate the nuclear choice", implying that the choices still have to be confirmed by further work. The siting of nuclear power stations requires large cooling facilities and off-shore plants is a solution to be studies. Nuclear parks with great concentrations of power production are also recommended in order to reduce the problem of waste transportation. This solution will require the use of superconducting cables for economic transportation of electricity, with the additional benefit of reducing visual pollution associated with overhead cables and the losses from long distance transportation. Siting is a problem closely linked to acceptance by the general public.

6. <u>A geothermal view</u> : Naturally produced hot water from deep levels is already used directly to heat buildings in parts of some European towns (Budapest and Paris) or used to produce electricity (Larderello). If drilling techniques can be developed with a supportable cost, and if the materials problems caused by the possible corrosive environment and steam can be overcome, the use of the heat from hot rocks (which exist at a depth of a few 1000 m in various parts of Europe) may become a large source of energy, which could play a major role in future energy scenarios.

7. <u>A solar energy element</u> : In Europe, with the possible exception of its Southern regions, probably only small scale applications are foreseeable. When photovoltaïc cells are produced economically, a large industry can be founded to export solar power stations to the developing countries. The problems of the storage of the energy produced by this intermittent source have also to be solved.

8. Nuclear energy with $H_2$ or $CH_4$ as the main secondary energy source:

If the studies, in which Europe has been leading, in the decomposition of water by thermo-chemical processes using the HTR are successful, and if $H_2$ can be produced at low prices, this could be an ideal non-polluting system which will not consume natural resources. The oxygen produced is usable in other processes and will reduce the cost of hydrogen; when fuel cells can be manufactured economically, oxygen could be transported in parallel with hydrogen to allow large scale electricity production in small local installations. These will be non-polluting and very attractive from the standpoint of safety and silence. The HTR can also be used for a closed cycle gas system based on methane decomposition.

9. Nuclear fusion: There is a high potential for fusion once its feasibility is proven. If all the problems created by a very large scale use of fission reactors compel complete rejection or set a limitation on nuclear fission, then nuclear fusion becomes a clear and non-polluting alternative.

To the nine elements briefly described can be added the contribution from other sources : wind, tides, temperature gradients of sea water, the limited role of which will depend on both economic factors and strictly regional possibilities of practical applications.

The scenario elements are not entirely alternatives, and they will surely overlap. In some aspects they represent options. The time of introduction on industrial scale is probably the order we have given in our brief description. It is of major importance to make the right choice and to take the right decision, because the implication of each choice and the loss of flexibility can be tremendous, due to the size of the investments required.

But no choice can really be made without a very careful study of all the present and future ecological, economic, social and industrial implications of each scenario. The methodology of technology assessment is to be used. In the USA has now been created a special board and office linking together the House, the Senate and the major scientific bodies of the country

("Office of Technology Assessment") which has the responsibility of evaluating the consequences and impact of each technological choice. In Europe where several countries envisage such offices on a national scale we cannot afford to take our own problems less seriously, and this should be done at least on a Community basis. It is also no longer possible to leave the determination of the future of energy to the market forces and to short-term price considerations. No single Government, no single industry, no expert can make the right decisions without a global view. The points which we recommend be taken into account in technology assessments should include :

1. Economic factors : Price
   - Availability of reserves
   - Geographical distribution of reserves
   - Cost of investments
   - Time of depreciation
   - Cost of the distribution system and its depreciation
   - Flexibility of use
   - Storability
   - Foreign trade.

2. Ecological aspects: Thermal discharges
   - Smoke
   - Noise
   - Radioactive releases and wastes
   - Site-clearing after removal of the power plant
   - Visual pollution for plant and distribution system
   - Climatic effects
   - Seismic and subsidence effects.

3. Social problems : Acceptability of the general public
   - Safety of production, transportation and use
   - Siting of power plants.

4. Industrial problems: Availability of materials for both generation and distribution.
   - Availability of technology.
   - Production capacity.

This type of global study has to be made by the Community in close cooperation with the other major industrial countries. The time-scale for the introduction of each technique will depend in every cyse on the results from research, and this result will depend on the size of our effort. But if we consider each source only on its own merits without parallel consideration of all the other alternatives, we can be driven again to dependence on an oligopolistic situation, which in an international scene can very easily become a monopolistic one, as is presently happening.

We have to build up the ideal scenario for the year 2000, taking into consideration all the already mentioned factors and starting from the present situation, and consider also the projection in the next centuries. The creation of this year 2000 scenario requires most advanced techniques using mathematical models of the complex system and large computers, and can only be done with the active cooperation of the best specialized institutions in the world.

It is quite probable that we will have to decide that the European scenario for year 2000 will differ from the American one in some aspects. But it has to be compatible and integrated in a world consideration to avoid unbalances, particularly in the cost of energy.

The year 2000 scenario will be the guideline for our R & D recommendations and is essential for establishing the right priorities and for establishing objectives. This applies equally for the intervening periods year 1980 and year 1990.

The final report of our sub-group will require a long-term effort and the mobilization of all the available experts. The next part of this interim report contains some specific proposals for the Commission to submit to the Council of Ministers for the initial funds to start the projects the necessity of which is already well established. We will also require all the funding requested for the "soft side" of the effort, project planning, the technology assessments and the systems studies.

We strongly recommend that the Community also takes action :

- to assure the cooperation of the best people in each country;
- to assure the transfer of the technological know-how and expertise from one field of industry to other fields which is essential in many of the projects we shall propose;
- to increase the effort in the field of materials, but not in a generic way, but for the solution of the problems of many projects which are material-limited;
- to assure the industrial cooperation necessary for the construction of prototypes and subsequent exploitation;
- to assure the scientific and technological cooperation with all the major industrialized countries outside the Community;
- to assure continuous exchange of information;
- to avoid useless duplication of efforts.

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## V. RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT!

The work of the Subcommittee has concentrated on three essential areas :

- how to conserve energy and improve efficiency of energy utilization;
- how to rapidly increase indigenous energy supplies, maximizing the production of coal, oil and gas and substituting oil by other energy sources (including nuclear power);
- how to develop new technologies.

The Committee estimates that solving the energy crisis is a major goal to be looked at in its entirety. It is a problem that will require the mobilisation of all the concerned partners of the Community, i.e. national Governments, industrial enterprises, research stations, etc. The problem is of such depth and size that it can be usefully tackled only within the framework of the Community. This implies on the one hand encouraging division of labour and specialization, on the other hand coordination and cooperation.

The Committee is fully aware of the very preliminary state of its work but nevertheless feels it is necessary to attempt quantification of its recommendations in order to enable the Community Institutions to implement action as from 1975.

The Committee believes that in order that the Community Institutions be in a position to promote stimulation and provide coordination, the sum at their disposal to support the European strategy for Energy R & D must not be too small in comparison with the total amount being spent in this problem area by the Nine. An indicative figure of some 100 to 150 Mua/year appears to be the minimum figure required to ensure a significant impact of the Communities on the total Energy R & D picture. It should by no means be read as a budget, but should rather be considered as a very preliminary estimate of what the Council of Ministers might be called upon to provide against specific projects and other types of action to be spelled out. It is only after serious analysis, based inter-alia on Community-sponsored studies to be launched in 1974, that first concrete indications of budgeted programmes can be made with a view to implementation in 1975. However, based on the preliminary studies and discussions, the Committee feels it can venture to draw attention to the following priority areas :

1. Economisation and conservation of energy;
2. Increasing indigenous supplies of oil and gas;
3. Substitution of oil :
    a) by coal;
    b) by removing obstacles to the introduction of nuclear energy for electricity generation;
    c) by nuclear energy for uses other than electricity generation.

4. The Hydrogen Energy System.

5. Other methods of transport and storage of energy.

6. New non-conventional energy sources :

   a) geothermal and solar,

   b) fusion.

The ways the Community can be effective range from funding studies and systems analyses of new and/or advanced proposals (Community contribution 50-100%), to guarantees and participation in first-of-a-kind marginal costs and risk coverage to be given to pilot and/or demonstration plants.

A detailed list of specific projects is below (Appendix B).

Appendix A

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- Mr. Paul METZ (represented by Mr.Sadeler)
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EXPERTS.

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  ERAP
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- Mr. Walter C.L. ZEGVELD,
  Adjunct-Directeur T.N.O.
  <u>Den Haag</u> (Nederland)

Part of the meetings were also attended by the Chairman of the C.E.R.D., Prof. Hendrik CASIMIR.

The technical assistance and secretariat to the subgroup activities were provided by the S.C.I.E.N.C.E. Consultant Company (Bruxelles) under contract (No.084-73-12-ECl-B) with the Commission of the European Communities.

Appendix B

## SUMMARY OF POTENTIAL RESEARCH PROJECTS.

### ECONOMIZATION AND CONSERVATION OF ENERGY.

- global analysis of most efficient combination of fuel supplies, energy transformation and uses;
- optimized urban systems;
- optimized housing;
- more efficient stationary or mobile engines;
- gas turbine-boiler combination topping-systems;
- use of lower-end heat power plants;
- reduction of losses in power transmission and distribution;
- recycling metals, plastics and glass;
- energy from waste.

### INCREASES OF INDIGENOUS SUPPLY OF OIL AND GAS.

- improvement of the knowledge of the inventory of the Community resources;
- general, offshore and deepsea exploration and exploitation techniques;
- improvement of secondary recovery.

SUBSTITUTION OF OIL BY OTHER ENERGY SOURCES.

1. Coal and lignite.

- assessment of advanced mining techniques;
- modelling of the fossil fuel system;
- fluidized combustion and stack gas desulfurization plants;
- two combined cycle gas turbine/steam turbine demo plants;
- topping and bottoming cycles;
- 2 pyrolysis and 2 solvent extraction units;
- fluidized bed type synthesis gas production plants;
- hydrogasification plant for lignite;
- synthetic crude oil (500,00 t/y coal).

2. Nuclear Fission Reactors for Electricity Generation.

(details to be considered).

3. Non-electrical Use of Nuclear Reactors.

- "Process heat" HTR-project.

Stretching of fossil fuels:

- heat exchangers;
- safety and reliability of chemo industrial complexes with nuclear reactors;

Hydrogen energy system;

- hydrogen market potential;
- hydrogen transportation and storage;
- hydrogen fuelled ground and air transportation vehicles;
- hydrogen safety;
- hydrogen fuel cells.

Paraconventional production:

- electrolysis

Thermochemical decomposition of water:

- material and heat transfer tests;
- chemical engineering studies;
- nuclear reactor design;
- alternative energy sources.

4. Marine Propulsion

R & D support for demonstration.

ENERGY TRANSPORTATION AND STORAGE: TRANSPORTATION.

Gas transportation systems.

Storage.

- hydroelectric pumping;
- compressed gas;
- Use of decommissioned mines for hydraulic storage.

NEW NON-CONVENTIONAL ENERGY SOURCES.

1. Geothermal Energy.

- prospecting inventorisation;
- hot dry rock projects;
- technologies for deep-drilling in igneous rocks;
- drilling in hot corrosive environment;
- low-temperature dual fluid cycle;
- solubility and corrosion problems;
- moni oring waste.

2. Solar Energy.

- habitat application;
- large scale ground electricity production;
- photovoltaic conversion;
- bioconversion.

3. Thermonuclear Fusion Energy.

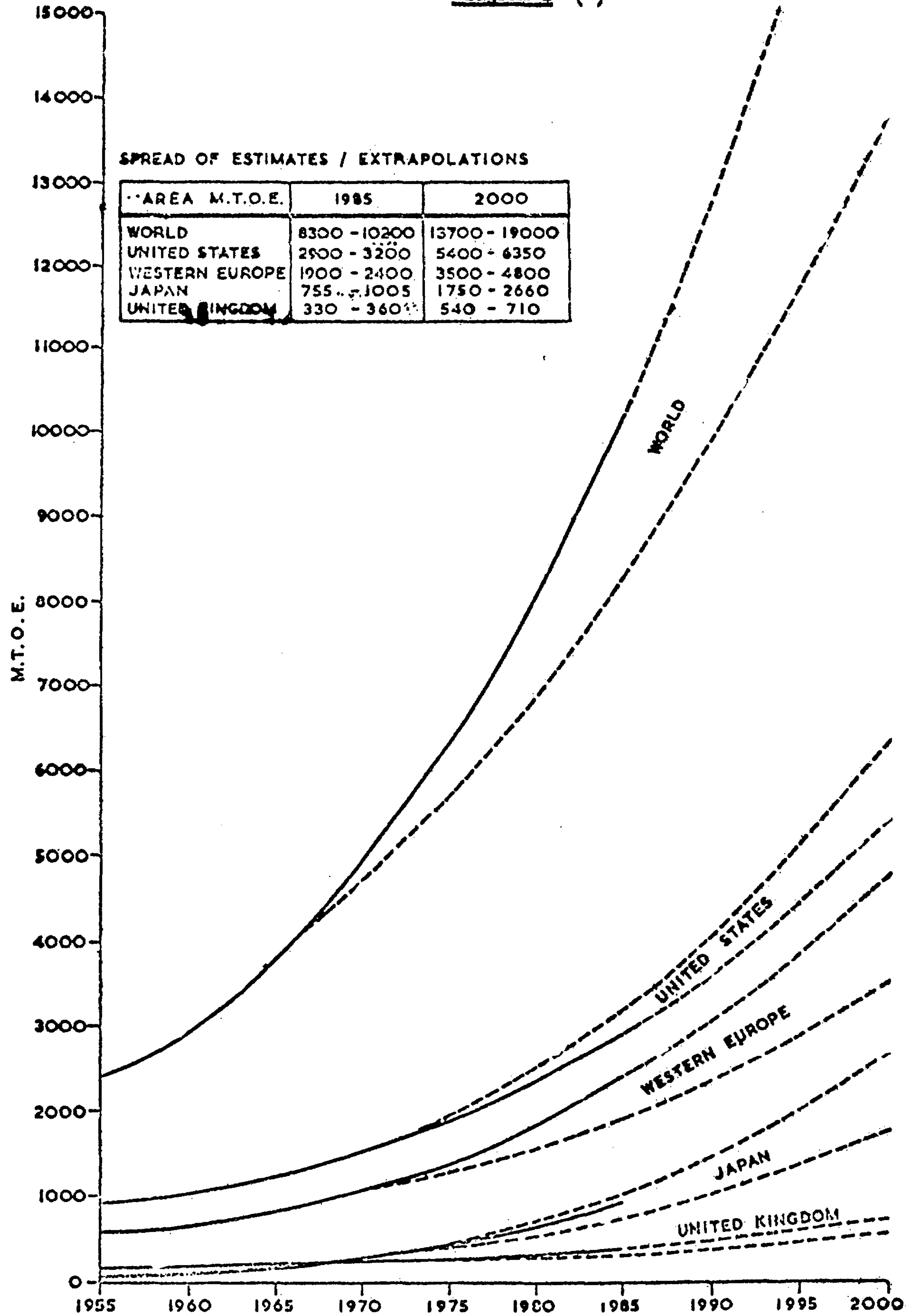
ELEMENTARY SCENARIOS.

- dynamic model of the Community energy systems;
- assessment of technological options;
- quality of life and energy consumption.

GLOBAL SCENARIO.

- the year 2000 energy scenario and its implication for the Community on year 1980 and 1990 scenarios.

Diagram I (+)




| AREA M.T.O.E. | 1985 | 2000 |
|---|---|---|
| WORLD | 8300 - 10200 | 13700 - 19000 |
| UNITED STATES | 2900 - 3200 | 5400 - 6350 |
| WESTERN EUROPE | 1900 - 2400 | 3500 - 4800 |
| JAPAN | 755 - 1005 | 1750 - 2660 |
| UNITED KINGDOM | 330 - 360 | 540 - 710 |

Fig.1 WORLD ENERGY CONSUMPTION TRENDS

(+) By permission of the Institute of Fuel, from "Energy for the Future"

**Diagram 2 – Energy requirements, and shares of indigenous and imported fuels for the Community of the Six (1970 – 1985)**

**Total primary energy requirements**

**1975-1985 Prospects**

| | in M tec | | | | in % | | | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1975 | 1980 | 1985 | 1970 | 1975 | 1980 | 1985 |
| Solid fuels | 223 | 195 | 185 | 174 | 23 | 16 | 12 | 9 |
| Oil | 617 | 831 | 1049 | 1304 | 64 | 67 | 66 | 65 |
| Natural gas | 73 | 150 | 225 | 295 | 8 | 12 | 14 | 15 |
| Primary electricity | 50 | 64 | 121 | 222 | 5 | 5 | 8 | 11 |
| Total requirements | 973 | 1240 | 1580 | 1995 | 100 | 100 | 100 | 100 |

**Share of indigenous and imported energies**

**Assumptions 1975-1985**

| | in M tec | | | |
|---|---|---|---|---|
| | 1970 | 1975 | 1980 | 1985 |
| Internal consumption | 844 | 1095 | 1415 | 1810 |
| Share covered by indigenous production (1) | – 325 | – 390 | – 470 | – 625 |
| Balance to be covered by imports | 519 | 705 | 945 | 1185 |
| Share of imported energy in % | 61 % | 64 % | 67 % | 65 % |
| Total requirements (2) | 974 | 1240 | 1580 | 1995 |
| Share covered by indigenous production (1) | – 325 | – 390 | – 470 | – 625 |
| Balance to be covered by imports | 649 | 850 | 1110 | 1370 |
| Degree of energy dependence in % | 67 % | 69 % | 70 % | 69 % |

(1) Amount presented as a working assumption.
(2) Internal consumption + exports + bunkering.

From : Prospects of primary energy demand in the Community [SEC(72) 3283 final]


Diagram 3
0 50 100 150 km
> 1000 million bbls
500 – 1000 million bbls
100 – 500 million bbls
< 100 million bbls
discovery well
Mainly Oil
Oil and Gas
Gas only
Oil Refinery
Water Depth in metres
Thistle
Cormorant
Brent
Frigg
Beryl
Heimdall
Piper
Forties
Montrose
Cod
Ekofisk
Tor
Josephine
Argyll
Rough
West Sole
Amethyst
Viking
Indefatigable
Leman
Groningen
Emsland
Amsterdam
London
East Midlands
Brussels