COMMISSION OF THE EUROPEAN COMMUNITIES

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ENERGY FOR EUROPE

RESEARCH AND DEVELOPMENT

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REPORT

of the

E N E R G Y P R O G R A M G R O U P

MARK II (modified)

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Introduction to the Modified Version of Mark II

1. Mark I and II of the Group's Report were based on crash efforts and intended for restricted use. In order to be annexed to an official document for wider circulation, Mark II had to be modified in some regards. Still, it represents the actual state of efforts which ought to be continued.

2. The approach of this paper can be described as follows:

   a) As much information as possible in as few words as possible.
   This leads to some condensations and asks for efforts on the reader's side.

   b) Statements or assumptions ought to be quantified whenever possible.
   This is a high risk approach, leading to criticism and corrections, but useful or even necessary because decisions ought to be prepared on at least a semi-quantitative basis. This stresses the necessity of a systems approach to the energy situation, and for research and development.

3. Priority criteria have to be considered when distributing a limited amount of money on various energy research and development possibilities:

   As to the general criteria: R + D actions should be part of a coherent global energy strategy, promising an impact on medium and long range energy supply (the short range being taken care of mostly by rational use of existing energy sources). The most promising strategy can be characterized by keywords like: coal and SNG; HTR and FBR; electricity and gas distribution grids. Inherent part of such a European system is the choice of sites for major installations leading, inter alia, to the "power park" conception, enforced also by safety and ecological considerations and eventually coupled to "assembly line" reactor production (on shores).

   The resources of the European system have to be quantified and fed into the considerations, as e.g. the national resources, the intellectual resources, the technological infrastructure and the forecasted economic situation, because a large part of the expenditures will have to be financed or guaranteed by public funds.

4. Specific criteria for coordinated Community efforts tend to: preserve the optimum and most efficient mix of the potential available.
   Vital injections should be concentrated at the right spot and not in fields of industrial activities already well established nor to general research financed within the framework of the education system. In order to solve these questions, an inventory of the efforts underway and planned in the Member States of the European Community is a necessary (if not sufficient) condition.

5. The main motivations and argumentations for a common approach to the energy problems are financial ones. Money will be scarce and waste no longer admissible. The maximum savings possible until the end of the century would markedly increase the "marge de manoeuvre" of the national budgets.

6. The primordial efforts to develop large substitute energy sources should not be considered as an outflow of oldfashioned autarky but rather as a necessary and urgent effort to restabilize the world system.

   It is hoped that we will live up to the challenge.

15.7.74

R. Lindner
Chairman

ENERGY PROGRAM GROUP

Introduction to Mark II

1. The Working Group submits Mark II of its report following the up-dating schedule with two months' intervals. Our hesitation is still there; modesty is overcome by the sense of urgency.

2. In the meantime, the danger of the energy crisis has partly been overshadowed by the danger that it may not be taken seriously. This may be a very grave mistake, indeed. In fact, in preparing Mark II, we have been impressed by the observation that it is "later than you think".

3. The introduction of large-scale nuclear energy, in spite of its drawbacks, is not an option but a "must".

   The time delays are terrifying, and this is not only valid for nuclear power plants but also for the large installations in upgrading and substituting energy like coal gasification plants coupled or not with nuclear reactors.

4. The enormous investments involved necessitate, amongst others, three things:
   - an optimum siting strategy to be decided upon rather soon;
   - a large allotment of public funds to guarantee industry engaged in coal mining and coal gasification their long-term investments,
   - optimizing the output of existing power plants (running at an average at about only 60% of their capacity) in order to gain money for future investments. This may involve large-scale energy storage.

5. In our internal working instructions, we have stressed the necessity to try a first inventory of energy research in the EC.

   This latter action has just started and must be pursued also on the basis of political goodwill generated by the respective authorities. The first statement is rather negative and ought to be formulated in a negative way:

   There is at present no evidence that an adequately funded and coordinated R + D effort is operative in the EC. The needs of the Europeans of the year 2ooo must be covered, be it by patchwork, be it by one fabric.

March 2o, 1974

R. Lindner
Chairman

ENERGY PROGRAM GROUP
(Groupe ad hoc de hauts fonctionnaires
spécialisés dans le domaine de l'énergie)

Introduction (to Mark I)

1. Respecting the deadline of January 15, the Group submits - with some hesitation - a paper which ought to be treated as a working paper or a first draft of a report rather than a final report (which may develop from it).

2. Following the instructions of Commissioner Professor Dahrendorf in his telex of December 6, 1973, the Group, composed of members from six General Directions, started work on December 1o, 1973. After distribution of tasks and preparation of contributions, a workshop meeting took place on January 9, 1o and 11, 1974.

3. The mandate is :

   - to establish a first inventory of research activities (in the energy field) executed in the Member States on basis of information available within or outside the Commission's Services;
   - to examine the current research projects - included those within the Community program framework - in the perspective of the present needs in the energy field, and
   - to analyse whether - in the frame of these research activities - there are lacks or omissions or if one or the other of these activities ought to be reinforced.

4. The three main functions, viz., to inventory, to analyse, and to suggest on basis of inventory and analysis, can be performed in principle with any amount of manpower, time and intensity. The time factor being the main bottle-neck (nearly prohibitive deadlines), the only practical method is that of successively ameliorated drafts, "sweeping" the field repeatedly with ever increasing precision. Simultaneously, quantification as a basis for judgement using priority criteria, had to be introduced from the beginning. Finally, a common language and working technique had to be adopted for the Group.

5. As to the inventory of research activities in the Community, an action of questionnaires was initiated by specialized services of the Commission already some months ago, and the results may be used by the Group as soon as they become available.

6. Besides, the enterprise will profit from the contact with the sub-group "Energy" of the European Committee for Research and Development (CERD) and by the increasing contact with other experts, especially in the field of fossil fuels (the present members of the Group deriving their competence mostly from the nuclear field).

7. A certain fallout from our deliberations may result for the imminent revision of the multi-annual program of the Community's Joint Research Center.

8. The present R + D impact of the analysis is partially elaborated, but in some chapters has still to be added in the next draft.

January 15, 1974

R. Lindner
Chairman

Chapter 1: ENERGY STATISTICS AND CONSERVATION

Some Statistical Information

§ o1 In 1972, the present European Community had an internal total energy consumption of 126o Mtec (million tons coal equivalent). The dependency on imported energy was 6o.8%, the per head consumption 4.95 tec/yr. Distribution on the energy carriers was as follows: crude oil 59.5%, coal 21.5%, natural gas 11.6%, primary electric energy 4.5%, lignite 2.8%.

§ o2 Distribution of the primary energy carriers on the various energy-consuming sectors can be estimated to be about:

38.3% for households (including minor industries),
38.6% for industries,
14.9% for transportation,
8.3% for the so-called energy sector (energy consumed by producers and transformers (of energy) to operate their installations).

Independently it might be remembered that 21.8% of the primary energy carriers went into the conventional fossil fuelled production of electricity, which latter was equivalent to 7.7% of the internal total energy consumption.

§ o3 Energy Carrier Production and Energy Consumption for the various countries of the Community in 1972.

Germany	consumed	355.o86	Mtec and produced	171,632
Great Britain	"	3o6.639	" " "	155.o33
France	"	235.2oo	" " "	61.o4o
Italy	"	173.o62	" " "	34.547
The Netherlands	"	82.492	" " "	69.56o
Belgium	"	63.171	" " "	9.622
Denmark	"	27.85o	" " "	o.112
Ireland	"	1o.o56	" " "	2.28o
Luxembourg	"	6.76o	" " "	o.o32

§ o4 Price Development of Crude Oil.

197o/71 Middle East oil had a price of $ 1.6 per barrel (159 litres) (This price might be reached for the exploitation of surface oil shales). In 1972 the price had risen to $ 3.5, and January 1, 1974 the OPEC countries have fixed a posted price of $ 11.65 per barrel. The oil companies' share can be sold at about 2/3 of the posted price, but the necessary part of "government oil" keeps the price at $ 8 - 9 per barrel for the first half year 1974 (about 55 UC/t free European port).

§ o5 Oil Imports and Consumption

The importation of crude oil into the Community of the Six was about 445 Mtons in 1972 as compared with the negligible production of 11.4 Mtons.

The main imports at the end of 1972 came from Saudi Arabia with about 12o Mtons, Libya 75 Mtons, Kuwait 55 Mtons, and the Iran about 5o Mtons.

The total imports in the Member States were remarkably equal as to the larger nations (Italy 118.8, Great Britain 1o7.7, France 1o7.6, Germany 1o4.4), whereas the Netherlands imported 67.8, Belgium 36.2, Denmark 9.7 and Ireland 3 Mtons.

§ o6 Of the about 537 Mtons of crude oil imported by the Community of the Nine in 1971, 321 came from the Near and Middle East, 183 from Africa, thereof 1o5 from Libya, 43 from Nigeria and 25 from Algeria.

§ o7 In 1971, the EC refineries of the Nine produced about 51o Mtons of petrol products distributed (in Mtons) upon: 199 fuel oil (residual), 1o6 diesel oil, 64.5 motor gasoline, 26.1 naphta, 14.4 bitumen and 13.9 aviation fuel.

§ o8

Hard coal production in Mtec (1972)		underground miners (March 1973)	output/manshift in tons
Great Britain	1o9.383	1826oo	3.769
Germany	1o3.549	1176oo	4.5o3
France	27.142	489oo	2.8o9
Belgium	9.487	21ooo	2.667
Netherlands	2.761	36oo	3.739

§ o9 Coal Imports

The overall importation from third countries to the present Community in 1972 was 31.629 Mtons.

12.986 Mtons were imported from the United States.
Among the Eastern countries, Poland is the largest supporter with 9.734 Mtons in 1971, followed by the Soviet Union with 3.9o8, and Australia with 2.237 Mtons (all in 1971).

Rational Use of Energy

We suggest the following subdivision:

I. Efficiency changes in the transformation of energy, related to a base (normal) value and thus to be considered as a) efficiency recovery and b) efficiency increase, respectively.

II. Various degrees of confinement of energy as to amount and form desired, again related to a "normal value", a) to be reached or b) to be surpassed, respectively.

Evidently, the "a" actions can be enforced by legislation (e.g., I.a: motor car exhaust; II.a: thermal insulation building codes), whereas the "b" actions can be initiated by financial incentives (eventually leading to new base values).

§ 11 Considerable amounts of energy can be saved in the EC (oil constituting a major share) by rational use of energy-at an average annual rate of 1% of the total energy consumption until the end of the century (the savings rate will be larger at the beginning, decreasing asymptotically). In the following estimates are made as to the composition of those, at least, 25%:

Efficiency Recovery:

General industries' contribution (optimum tuning of energy-consuming units) could amount to 2% or more.

By enforced optimum use of fuels (better tuning of motor car engines, etc.), the transportation sector might realize savings of another 2%. (In addition, speed limits and reduced circulation (no weekend driving) can easily subtract another 3%, as exercised in Western Europe in winter 1973/74).

Efficiency Increase:

§ 12 On the domestic and industrial sectors, improvements in oil or gas-burning efficiency could still be made, especially with regard to maintenance-free burner and monitoring equipment. This could also raise the old question of stack optimization; stack gas temperatures have to be reviewed and ameliorations by forced ventilation and resistant stack linings be considered.

As to large consumers of electric energy (metallurgical industry), the rising fuel price will automatically enforce a better utilization and an improvement or substitution of existing processes. Legislative intervention seems superfluous.

A minor contribution to energy economies is the use of hydro-gasification processes for organic wastes from composite municipal refuse which may amount to 1/2 mill. cb.m. synthetic natural gas for a city of 1 mill. people. This is no large contibution, but presents the advantage of simultaneously solving part of the waste disposal problem.

§ 13 In the following we shall in a rather short way deal with technological developments which may result in another 1o% economy:

Apart from reglementation, better management of energy and technical developments, increasing the efficiency of existing transformation devices or introducing new ones, can achieve savings in energy and money.

In electricity production, successive substitution of antiquated plants by modern ones would increase the actual average transformation efficiency from 34% to 41%, equivalent to relative energy savings of 2o% in that field; this corresponds to absolute savings of 5%. Assuming the normal replacement rate of fossil fuel plants, this could be accomplished before the end of the century. Many of the replacements may be on nuclear basis, the introduction of nuclear electricity plants with a higher degree of efficiency would yield the same result, especially if high-temperature reactors are used.

The essential introduction of gas turbines as topping devices permits considerable gains, especially if material development allows the utilization of gas temperatures of 16oo to 18oo^{o} C, which would raise the overall efficiency to 6o%, another relative gain of 5o% as compared to the present 4o% efficiency

This question is intimately coupled with the use of hot gas either from reactors or from preferentially gaseous clean fuel, e.g., gasified coal. (Potassium vapor cycles seem to be too expensive for large-scale application.)

The contribution of bottom cycles, using organic compounds at low temperatures, is evidently much smaller.

§ 14 Heat pumps

Electrically driven heat pumps based on an evaporation - condensation cycle can improve room heating systems in the following ways:
Room heating: Heat of a temperature of at least 5 - 1o^{o}C will be pumped from a heat reservoir, like outside air, river, sea or underground. Investment costs are tolerable and efficiencies high enough (e.g., 3 kWh thermal pumped by 1 kWh_e) if the temperature difference is not exceeding 5o^{o}C.

Solar energy influx may be sufficiently high to heat an exposed reservoir of about 1o^{o}C for an effective application of heat pumps.

The reversed Stirling engine (§ 521) could be advantageously used as a heat pump.

§ 15 Energy Confinement:

Savings would be largest in the domestic field (essentially diminuation of heating energy losses), amounting to some 8% of the total energy.

On the domestic sector, utilization of low-temperature waste heat (large quantities in toto) is an urgent problem. The idea of a "domestic hot waste water recycling machine"is reported to be under study.

A considerable energy conservation potential (hard to quantify) is hidden in the conception of increasing the durability of consumer goods (e.g., Mansholt 1972). It is partly an urgent task of legislation, because it presupposes the existence of a high standard of living, but at the same time tends to stabilize this very standard of living, setting an end to excessive consumption habits. The energy costs for large productions like steel, glass, paper, aluminum and cement are 3o - 5o% of the products' value.

§ 16 A point essential for the future (especially for nuclear energy) will be the optimization of central large power generating units (power parks) with short transmission lines to large consumers (e.g. chemical industry) and new ways of far-distance energy transmission (hydrogen). Details are given in later chapters.

§ 17 In the same way, the optimum utilization of energy by degradation in sequential use in as many steps as possible could be enforced, once systems engineering has found the optimum solutions.
Light energy in buildings could be economized by the use of a central light source (preheating warm water) and using light pipes.

§ 18 Although the EC transport sector consumes only 14% of the total energy, economies are highly desirable because of its high dependency on imported oil.

Transport shift from road to rail helps this situation, especially if combined systems are used like container trailers in a pick- a back system. Besides, very simple special, e.g., electric cars, their batteries being recharged on the train, might be a future solution to fuse long- distance and short-distance transport.

But also the existing passenger cars allow economies: less weight and aerodynamic resistance, radial tires; better fuel injection systems and high compression ratios (1:9-10) for I.C. gasoline engines fuelled with 10-15% methanol are simple and effective measures. The higher efficiency of gasoline/methanol mixtures saves 6%, and the high compression ratio avoids a penalty of about 10%, otherwise probably enforced by reduction of antiknock additives, leading (methanol production needs being subtracted) to a net gain of 10%, applicable to about one third of the oil fuelled transportation sector. Environmental problems are solved at the same time by a 75% reduction of exhaust CO and some reduction of NO_x. Other possibilities are more efficient power trains and more Diesel engines (with benzpyrene-free exhausts) and optimized city traffic systems.

Chapter 2 : NON-IMPORTED FOSSIL FUEL, ESSENTIALLY COAL

§ 21 Oil and natural gas. The known on-shore reserves of oil on the Community's territory are only in the order of 1oo to 2oo Mt. The North Sea shelf reserves, however, are estimated at 1ooo Mtons or more, and optimistic assumptions state an annual production of more than 1oo Mtons for 198o/1.

With natural gas, proven reserves are estimated at 2ooo Gm^3, and probable reserves are expected in the same order of magnitude. (1 Gm^3 natural gas = 1.14 Mtec). It is hoped to annually draw 8o to 9o Gm^3 of natural gas from the North Sea bottom in 198o.

Deep-drilling may open new reserves and is planned on-shore and off-shore in the Community, off-shore essentially in the North Sea, but also in the Bay of Biscay and in some basins of the Mediterranean. In 198o, off-shore drillings may go down to 1.ooo m, on-shore drillings with a target of>7.ooo m.

§ 22 Oil shales. Proven reserves in surface shales are small, e.g., 2oo Mtec in Germany , distributed on comparable amounts in northern and southern Germany. Extraction of oil is expensive and up to now was not competitive; economics normally demand a utilization of the waste material in the cement industry. In favourable cases, the extraction of heavy metals (uranium in Sweden) favors the economic balance.

Underground oil shales, not to be strip-mined, may be larger in order of magnitude but demand the development of sophisticated extraction techniques (in situ ?).

§ 23 Coal

Coal (lignite included) constitutes about 8o% of the probable and known fossil energy resources of the Community, considerable reserves existing in the U.K. and Germany. Still, the probable resources in coal down to 12oo m and with a thickness of 3o cm and more amount to not more than 85,ooo M tec, covering the 1972 total energy consumption of the European Community for a period of 65 - 7o years. Thus, coal cannot substitute nuclear energy in the long run and considerable imports have to be envisaged, especially during the critical period until the end of the century when coal has probably to take over many of the essential functions filled by oil today. The availability of coal has to be increased, not only by increasing imports (if possible) but also by increased production. If optimistically targetting a 1oo% increase of coal availability until 1985, half of that increase might be covered by a production increase estimated to about 4% annually and essentially covered by a gradual increase of production per manshift from 4 to 6 tons. The other half of the availability of coal ought to be secured by increased imports. This seems more realistic than the reactivation of deserted coal mines or a very large increase of underground miners from the present 365 ooo miner force in the Community.

This necessitates long-term investments, probably only possible on basis of government guarantees and, if necessary, subsidies (as in the past). With regard to the utmost medium-term importance of such measures, a shared risk and a shared benefit amongst the member states of the Community seems reasonable.

It should be remembered that coal (and lignite) still cover 74% of the primary energy for electricity generation in Germany and 64% in the U.K.

Underground gasification, considered in the United States, at present shows a feeble chance of success because, quite apart from the enormous technological difficulties, the low-power gas being obtained (9oo Kcal/kg) has to be burnt near the mine and can hardly be fed into the distribution grid.

As to the better utilization of coal in situ, under favorable conditions, the process of liquefaction (e.g., by solvent extraction) can be considered, but there is no real experience yet and not much hope for EC conditions.

§ 231 Coal gasification is a comparatively old industry and several smaller plants are still in operation within the Community and outside (or being built), using bituminous coal and lignite. At present, the gasifier ratings, however, are only up to about 1ooo Mbtu per day. Coal gasification normally uses water vapor, leading to hydrogen and carbon monoxide (or carbon dioxide with water excess and lower temperatures). In the Lurgi gasifier, the partial burning of the coal with oxygen and the reduction are performed simultaneously and continuously.

The primarily formed low-power gas can be enriched catalytically to a high power gas of about 1,ooo BTU/scf , essentially consisting of methane.

Both processes, the Lurgi gasification and the methane enrichment are at present executed in Westfield (Scotland), a testing ground for various types of American coal.

Another Lurgi installation of 17o MW , using gas turbine topping cycles, is installed in Lünen (Germany).

§ 232 Application of Nuclear Heat for Coal Gasification

As a considerable part of coal's energy is lost in the production process (about 3o% for SNG)+, the application of cheap nuclear heat to coal gasification presents itself as a measure of economy and resources conservation.

Obviously, this necessitates the rapid introduction of a large number of high-temperature gas-cooled reactors with helium outlet temperatures sufficiently high for reactions like, e.g., partial or complete steam reforming of methane (about 8oo - 9oo°C).

In this case, the initial hydrogenation of coal ought to be performed at lower temperatures with direct addition of hydrogen produced by nuclear heat (methane steam reforming or hydrogen production by chemical cycles). The reactor itself would only take over the reforming step.

(For direct production of SNG, helium temperatures of 11oo°C would be needed).

In this context, a very interesting suggestion by Professor Schulten in Germany should be mentioned:

+) SNG: Synthetic (or Substitute) Natural Gas

2

Partial steam refining of methane to carbon monoxide and hydrogen could take place by means of an HTGR at 7oo - 8oo°C. This increases the molar energy content of the gas by about 5o Kcal/mole. The mixture can now be fed into a circuit, pumped over distances up to 5o km to energy release stations, where the back reaction to methane is taking place at temperatures below 5oo°C in small reaction units in which the catalytically accelerated reaction produces heat and water which, after condensation, can be used, whereas the methane is recirculated in a closed circuit back to the reactor, etc. There is a net transport of energy and water from the reactor to the consumer. The initial methane need not even be produced but can be bought as a pure gas because, apart from minor leaks, no replenishment would be necessary.

Such a distribution grid would have all the advantages of gas distribution, and last, but not least, also a certain storage space in the distribution grid itself. Temperatures are not excessive, the released heat can be used as process heat or for domestic purposes (heating, hot water) or even for driving minor steam turbines and preferentially in a carefully calculated cascade of all these single energy degradation processes. Of course, a large amount of water would be needed and consumed, another case for careful reactor siting. But eventually, also part of the water, if not polluted excessively, could be re-used and recirculated in a more or less closed circuit.

Such installations could be corner-stones of a European system if the gas composition and quality is maintained within narrow limits. The smaller temperature drop between the temperature of the coated particles and the helium outlet favors the pebble-bed reactor as compared to the prismatic fuel elements reactor.

The main gas outlet of the reactor could transport energy equivalent to a power of 2,ooo MW with a pipeline diameter of 1 m, a gas pressure of 7o atm and a gas velocity of 3o m/sec, equivalent to an energy flux of 3oo KW/cm^2.

Thermodynamic Tables for Conversion of Fossil Energy Carriers

In the following tables thermodynamic data for some reactions, mainly coal gasification and reforming processes involving methane and methanol, are listed according to the international thermodynamic notation.

The total energy ΔH is equal to the heat absorbed (+) or released (-) in a reaction, whereas the sign of Gibbs free energy, ΔG (related to the equilibrium constant K), indicates whether or not the reaction is possible at the temperature given.

Negative ΔG values, corresponding to K values >1, indicate that the reaction is possible. Positive ΔG values (or K values < 1) indicate that the reaction will proceed in the opposite direction.

ΔG corresponds furthermore to that part of the energy which can theoretically be obtained as electrical energy in case of a fuel cell reaction (or is absorbed in electrolysis).

The thermodynamic values are given for temperatures of 3oo, 5oo and 1ooo^{o}K, corresponding roughly to room temperature, low process heat temperature and high process heat temperature as being obtained by high-temperature reactors.

As ΔH and ΔG values are additive, reactions can easily be calculated utilizing the data for elementary reactions. E.g., the Boudouard equilibrium is obtained by adding twice the values for the CO formation reaction to the values of the CO_2 - decomposition.

$$CO_2 = C + O_2 \quad - (\Delta H, \Delta G)_{CO_2}$$

$$2(C + o{,}5\ O_2) = 2\ CO \quad + 2(\Delta H, \Delta G)_{CO}$$

$$\text{Sum :} \quad CO_2 + C = 2\ CO \quad (\Delta H, \Delta G) = -(\Delta H, \Delta G)_{CO_2} + 2(\Delta H, \Delta G)_{CO}$$

A. Formation and Reforming of Fuels

1) Hydrogen Formation ("Watergas") ($C + H_2O \rightarrow CO + H_2$)

500°K : ΔH = +31.979 kcal/M; ΔG = −15.170 kcal/M; K = $4.26 \cdot 10^6$
1000°K : ΔH = +32.401 kcal/M; ΔG = + 1.792 kcal/M; K = 0.41

2) Carbon Monoxide Formation (Boudouard Reaction) ($CO_2 + C \rightarrow 2CO$)

500°K : ΔH = +41.515 kcal/M; ΔG = +20.027 kcal/M; K = $1.77 \cdot 10^9$
1000°K : ΔH = +40.774 kcal/M; ΔG = − 1.004 kcal/M; K = 1.66

3) Methane Formation ($C + 2H_2 \rightarrow CH_4$)

300°K : ΔH = −17.904 kcal/M; ΔG = −12.103 kcal/M; K = $6.65 \cdot 10^8$
500°K : ΔH = −19.702 kcal/M; ΔG = − 7.815 kcal/M; K = $2.72 \cdot 10^8$
1000°K : ΔH = −21.429 kcal/M; ΔG = + 4.615 kcal/M; K = $0.98 \cdot 10^{-2}$

4) Methanol Formation ($C + 2H_2 + 1/2\ O_2 \rightarrow CH_3OH$)

300°K : ΔH = −48.088 kcal/M; ΔG = −39.085 kcal/M; K = $3.11 \cdot 10^{28}$
500°K : ΔH = −49.713 kcal/M; ΔG = −32.110 kcal/M; K = $1.08 \cdot 10^{14}$
1000°K : ΔH = −51.960 kcal/M; ΔG = −13.480 kcal/M; K = $8.96 \cdot 10^2$

5) Hydrogen from Carbonmonoxide ("Watergas") ($CO + H_2O \rightarrow CO_2 + H_2$)

500°K : ΔH = − 9.536 kcal/M; ΔG = − 4.857 kcal/M; K = $1.32 \cdot 10^2$
1000°K : ΔH = − 8.579 kcal/M; ΔG = − 0.788 kcal/M; K = 1.49

6) Hydrogen from Methane ($CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$)

500°K : ΔH = +41.745 kcal/M; ΔG = +18.128 kcal/M; K = $1.20 \cdot 10^{-8}$
1000°K : ΔH = +45.617 kcal/M; ΔG = − 7.195 kcal/M; K = $3.76 \cdot 10^1$

7) Methane Reforming ($CH_4 + H_2O \rightarrow CO + 3H_2$)

500°K : ΔH = +51.281 kcal/M; ΔG = +22.980 kcal/M; K = $9.07 \cdot 10^{-11}$
1000°K : ΔH = +53.910 kcal/M; ΔG = − 6.407 kcal/M; K = $2.53 \cdot 10^1$

8) Methanol from carbonmonoxide ($CO + 2H_2 \rightarrow CH_3OH$)

300°K : ΔH = −21.687 kcal/M; ΔG = − 6.281 kcal/M; K = $3.79 \cdot 10^4$
500°K : ΔH = −23.422 kcal/M; ΔG = + 5.074 kcal/M; K = $6.06 \cdot 10^{-3}$

9) Methanol from Methane (Partial Oxidation) ($CH_4 + 1/2\ O_2 \rightarrow CH_3OH$)

500°K : ΔH = −30.411 kcal/M; ΔG = −24.295 kcal/M; K = $4.14 \cdot 10^{10}$
1000°K : ΔH = −30.531 kcal/M; ΔG = −18.095 kcal/M; K = $9.18 \cdot 10^3$

B. Combustion Reactions

1) Carbon oxidation, incomplete ($C + 1/2\ O_2 \rightarrow CO$)

Heat of Combustion at 1000°K : 2231 kcal/kg of C

300°K :	ΔH = -26.410 kcal/M;	ΔG = -32.804 kcal/M;	$K = 8.21 \cdot 10^{23}$
500°K :	ΔH = -26.291 kcal/M;	ΔG = -37.184 kcal/M;	$K = 1.78 \cdot 10^{15}$
1000°K :	ΔH = -26.769 kcal/M;	ΔG = -47.801 kcal/M;	$K = 7.28 \cdot 10^{5}$

2) Carbonmonoxide combustion ($CO + 1/2\ O_2 \rightarrow CO_2$)

Heat of Combustion at 1000°K : 3015 kcal/m³ of CO

500°K :	ΔH = -67.806 kcal/M;	ΔG = -57.208 kcal/M;	$K = 1.00 \cdot 10^{25}$
1000°K :	ΔH = -67.543 kcal/M;	ΔG = -46.747 kcal/M;	$K = 1.77 \cdot 10^{10}$

3) Carbon oxidation, complete ($C + O_2 \rightarrow CO_2$)

Heat of Combustion at 1000°K : 7859 kcal/kg of C

300°K :	ΔH = -94.049 kcal/M;	ΔG = -94.288 kcal/M;	$K = 5.44 \cdot 10^{68}$
500°K :	ΔH = -94.097 kcal/M;	ΔG = -94.395 kcal/M;	$K = 1.78 \cdot 10^{41}$
1000°K :	ΔH = -94.312 kcal/M;	ΔG = -94.598 kcal/M;	$K = 5.21 \cdot 10^{20}$

4) Hydrogen oxidation ($H_2 + 1/2\ O_2 \rightarrow H_2O$)

Heat of Combustion at 1000°K : 2645 kcal/m³ of H_2

300°K :	ΔH = -57.806 kcal/M;	ΔG = -54.608 kcal/M;	$K = 6.45 \cdot 10^{39}$
500°K :	ΔH = -58.270 kcal/M;	ΔG = -52.354 kcal/M;	$K = 7.56 \cdot 10^{22}$
1000°K :	ΔH = -59.250 kcal/M;	ΔG = -46.009 kcal/M;	$K = 1.19 \cdot 10^{10}$
3000°K :		ΔG = -17.147 kcal/M;	$K = 1.78 \cdot 10^{1}$

5) Methane combustion ($CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$)

Heat of Combustion at 1000°K : 8543 kcal/m³ of CH_4

500°K :	ΔH = -191.335 kcal/M;	ΔG = -191.288 kcal/M;	$K = 3.92 \cdot 10^{83}$
1000°K :	ΔH = -191.383 kcal/M;	ΔG = -191.231 kcal/M;	$K = 7.58 \cdot 10^{41}$

6) Methanol combustion ($CH_3OH + 1.5\ O_2 \rightarrow CO_2 + 2H_2O$)

Heat of Combustion at 1000°K : 5027 kcal/kg of CH_3OH

300°K :	ΔH = -161.573 kcal/M;	ΔG = -164.419 kcal/M;	$K = 10^{100}$
500°K :	ΔH = -161.134 kcal/M;	ΔG = -166.993 kcal/M;	$K = 9.46 \cdot 10^{72}$
1000°K :	ΔH = -160.852 kcal/M;	ΔG = -173.146 kcal/M;	$K = 8.26 \cdot 10^{37}$

Chapter 3: NUCLEAR ENERGY

Nuclear Fission Energy.

§ 31 The only new energy sources with proven potential for large-scale application in the near and intermediate future are nuclear fission reactors. The rate of their introduction on a large scale depends on several factors mainly of technical nature, as outlined in more detail below. However, it also depends on a decision in principle whether to accept or not to accept nuclear fission power with its advantages and disadvantages. The risks connected with nuclear fission energy necessitate major decisions as soon as possible, especially as to the introduction of "nuclear power parks" and their location; properly designed parks would minimize the risks involved with nuclear fuel fabrication, nuclear reactor operation, plutonium movements, reprocessing and final waste disposal.

The often cited problems of final disposal of alpha-radioactive long-lived waste have to be reconsidered in research and in various strategic models. However, they do not seem unsolvable+ and in our opinion should not block the introduction of large-scale nuclear energy.

§ 311 The only available fission resources are uranium (containing about o.7% fissile uranium-235) and thorium (which can be converted into fissile uranium-233).

The commercially established reactor lines are the LWR and the HWR (Light Water Reactor and Heavy Water Reactor). The first line uses enriched uranium but has proved cheaper than the second one.

LWR reactors draw from the limited fissile uranium resources. Even when recycling the converted plutonium they produce, they can make use of only o.7% of the natural uranium potential energy.

In order to avoid total depletion of the uranium resources, there are two possibilities:

- using the abundant thorium by developing HTR's which can efficiently convert thorium into fissile uranium-233 (conversion ratio o.6 -o.9),
- using breeder reactors(reaching breeding ratios of 1.2 - 1.4), allowing to fission the total amount of uranium atoms.

+) (also neutronic transformation of actinides may be considered).

For the medium-term perspective, it is desirable to build breeders having a compound doubling time of the same order as the doubling time of the electricity demand, i.e., 9 to 1o years (as extrapolated by the electricity producers).

For the long-term perspective, the equilibrium situation could be imagined where one breeder reactor fed with natural uranium, breeds the plutonium it needs and transforms Th-232 into U-233, feeding two to three HTGR's, depending on the respective breeding and conversion ratios. This combination would simultaneously produce electricity and high-temperature process heat.

§ 32 In the following we are comparing the advantages and disadvantages, not only of nuclear fission, but also of the various types of reactors on which considerable work has been done during the past. Three of them, viz., the light-water reactor (LWR), the high-temperature gas-cooled reactor (HTGR) and the liquid metal fast breeder (LMFBR), are the most seriously considered for the immediate future; of the other types of reactors, the gas-cooled fast breeder reactor (GCFR) deserves attention.

A -Generalities

Advantages	Disadvantages
- world-wide resources sufficient for many centuries without energy restriction.	- little U and Th ore resources in the Community.
- already competitive with conventional energy	- no massive immediate introduction possible
- clean power (practically no air pollution)	- radioactivity problems: - health safety - waste disposal - safety of installations - new and spent fuel transport - plant decommissioning - fissile materials safeguards - vulnerability of installations
- high compactness of fuel: 1 g U totally fissioned = 2.6 tec	

Therefore:

Concentration of large-size units in nuclear complexes might be required, entailing in particular energy transportation problems.

L W R

Advantages	Disadvantages
- commercially available	- needs U enrichment
- presently lowest KWh cost	- low load factor (at present)
-possible Pu recycling	- low thermal efficiency
	- needs water cooling
	- tritiated water production
	- safety aspects presently reducing performances

H W R (Candu type)

Advantages	Disadvantages
- commercially available	- Canadian technology
- no need for U-enrichment	- requires heavy water industrial production
- Th cycle possible (near breeder)	
- safety	- tritiated water production
- fuel reprocessing not absolutely necessary	
- high load factor	- low thermal efficiency
	- low performance (KW/Ltr. core)
	- higher KWh cost than LWR
	- requires water cooling

HTGR

Advantages	Disadvantages
- US prototype (3oo MWe) to be started in spring '74	- large R + D still necessary on reactor system, fuel cycle
- German prototype to be started in '77	
- possible competition for commercial bids by 1975	- based on US technology at that [illegible]
- Th and U cycles possible (near breeder)	- needs high U enrichment (Th cyc[illegible]
- high thermal efficiency with steam and gas cycles	- large R + D necessary on gas turbine
- high temperature process heat possible	
- safety	
- water cooling not required	

Advantages	Disadvantages
F B R	
- U enrichment capacity not needed	
- independence of U cost through breeding capacity	
LMFBR	
- two prototypes (25o MWe) started in Community	
- first 12oo MWe demonstration scheduled in Community in early 8os	R + D still necessary on reactor systems (Na technology), safety and fuel cycle
- possible commercial bids before 1985	
- Th cycle possible	
- good thermal efficiency	- needs water cooling
- European technology	- concertation to be improved
GCFR	
- high breeding gain	- specific inventory higher than LMFBR
- Th and U cycle possible	
- good nuclear safety (no void coefficient)	- depressurization (loss of coolant) problem
- uses HTGR technology	
Fuel pin type GCFR	
- uses LMFBR basic fuel technology	- needs some additional R+D on fuel (surface roughening and venting)
	- fission products in primary circuit
	- low thermal efficiency
	- large commercial scale not before 1995.
Coated particles fuel type GCFR	
- high thermal efficiency	- large R + D effort necessary
- high temperature process heat possibility	
- dry cooling tower possibility	

OTHERS

Other lines of reactor development do not appear promising at present (seed and blanket thorium LWR breeders, MSR concepts).

§ 33 Considerations on the Different Reactor Types

Nuclear energy is the only technology developed sufficiently to substitute fossil fuel for electricity generation. However, for obvious reasons, this substitution can only be progressive: from 8% in 1975 it could possibly reach 5o % around 199o and 8o% in 2ooo, corresponding to ~ 8oo GWe nuclear power installed in the EC.

- Light Water Reactors (LWR) have been adopted by all industrialized nations with the exception of Canada and maybe the U.K. The present steep increase of orders for nuclear generating capacity bears only on this type of reactor. Even though this does not seem to present bottlenecks from the reactor components and fuel fabrication capacity point of view, the necessary steps have to be taken to ensure skilled labor availability. On the other hand, considerable amount of uranium enrichment capacity+ should be ensured for the E.C.: roughly 11o TSWU are needed for 1 GWe yr. generated in LWR's (the presently committed annual EURODIF capacity is 9ooo TSWU); in the year 2ooo, Community enrichment services of 9o,ooo TSWU will be required.

- High Temperature Reactors (HTR) could contribute to electricity production around 198o, on the basis of the experience of the Fort-St-Vrain (U.S.A.) and Schmehausen (Germany) prototypes to be started up in 1974 and 1977, respectively.

Their essential advantages are to allow use of new natural reserves (thorium) and to open new fields of nuclear application in the chemical and metallurgical processes due to the high temperature supplied.

- Liquid Metal Fast Breeder Reactors (LMFBR) could be commercially available around 1985 - 199o on the basis of the Phénix (France), PFR (U.K.), SNR (Germany) and Clinch River (U.S.A.) prototypes, the dates of criticality of which are 1973, 1974, 1978-79 and 198o, respectively. This reactor type could ultimately give complete independence from enriched uranium sources.(An independence date from enriched uranium before 2ooo or 2o1o would nevertheless be impossible because of the necessary long delay necessary for the replacement of reactors requiring uranium enrichment by LMFBRs).

+)A plant based on the present diffusion technology requires 3% of the electric power that it permits to install in LWRs; ultra-centrifugation is claimed to do 1o times better.

It will be requested to minimize the doubling time of the fissile material inventory which implies development of advanced fuels such as carbides as well as shortening of the out-of-pile time with improved reprocessing methods.

- Gas Cooled Fast Reactors (GCFR) are being studied along two lines: a fuel pin type version using the maximum of the fuel technology developed for LMFBR's, which would give an outlet gas temperature of 56o^{o}C, and an advanced version with coated particle fuel, which would permit a much higher gas outlet temperature. The first version could be commercially available about 5 years after the LMFBR. Since the second version would require a large R + D effort, no estimate can be made at present.

§ 331 Naval Nuclear Propulsion

At present, 6 to 7% of crude oil consumption in the Community is used for ship bunker supplies. Due to the increase in oil prices, the competitive power threshold for nuclear propulsion has come down considerably (from 8o,ooo shp+) to 4o,ooo). On the other hand, there is the tendency to increase the ship power: the number of ships with power greater than 1oo,ooo shp is foreseen to increase from 2o in 1975 to 5oo in 199o. Added to the important economic incentive of using nuclear propulsion is now the possibility to avoid bunkering difficulties far from the bases. R + D effort is necessary on the reactor, nuclear safety, collision protection, fuel development (burnable poison). A joint undertaking in the sense of the Euratom Treaty could be created to build an "economic feasibility demonstration ship". If nuclear propulsion is introduced, a maximum guess would be that between 1985 - 199o about one third of the energy consumption for ship propulsion could be covered by nuclear fuel.

The electronuclear power installed in 199o is estimated to about 3oo GW_e. The nuclear fuel burned in a 1 GW_e land based reactor could allow the operation of 1o nuclear ships of 1oo,ooo shp each.

+) shp = shaft horse power

§ 34 Common R + D Work to be Undertaken in the Nuclear Fission Field

R + D work of common interest should be pursued in particular in the following fields:

- radiation protection
- safety of the installations under normal or accidental conditions
- understanding of basic phenomena involved in the fuel irradiation behavior (swelling, material displacement, fission product migration, ...)
- reprocessing methods
- disposal methods of radioactive wastes
- ultimate disposal of nuclear power plants after decommissioning
- forecasting and strategy studies
- siting studies
- nuclear ships
- development of advanced fuel elements, especially for LMFBR's.

The most recent papers which have been published for public funding of such type of R + D come from the U.S.A. They foresee an average annual expenditure of 5oo Mio. $. In the Community, there are no reasons to believe that the financial needs could be smaller.

§ 35 Thermonuclear Fusion Energy

During the last two years, the numerous programs of thermonuclear fusion have yielded essential progress in magnetic confinement fusion. Optimistic experts in the field assume that the feasibility of a magnetic confinement fusion, using the D-T reaction, will be demonstrated between 1978 - 1982. In this situation it appears that engineering problems would begin to be important from 198o on and investigations could be started now, such as on potential materials for use in fusion reactors.

In the past, expenditure on fusion research has been at the level of about 5o MUC annually both in the Community and in the U.S.A. In the U.S.A., proposals have been made for a substantial increase, to 1,2oo Mio dollars for the 5-year period 1975 - 79. Thus, to remain competitive, an increase in the Communities' research program is indicated.

The new method of laser fusion has equally registered 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. Part of the research falls into the military sector. In the U.S.A., laser fusion investment in the civilian sector is about 10% of that for magnetic confinement fusion, whereas in the Community it is far lower.

As to timing, a low power prototype running around 1990 and the introduction of large-scale fusion power at the beginning of next century, would make it an essential energy source. It should not be forgotten, however, that fusion is not established today and that it cannot contribute to the solution of the present energy crisis.

Table I : Fission and Fusion

Energy Source or Reactor Type	Scientific Chance of success	Technological Feasibility	Demonstration scale	Industrial scale	Additional R/ Development cost to industrial scale	Investment cost	Operational cost	% Thermal efficiency	Possible Nuclear Capacity installed GWe													Safety	Unfavorable Environmental Impact
									1975			1980			1985			1990			asymptote		
									min.	av	max.	min.	av	max.	min.	av	max.	min.	av	max.			
LWR	100	100	yes	yes	500	low	high	30		10			40		130		230		300	?		avg	+++
HWR	100	100	yes	yes	?	avg	avg	30		0			?			?			?			high	++
HTGR	100	100	yes	1980	500	low	avg	45		0			1		5		10	15		50		high	+
LMFBR	100	100	yes	1980	>1500	high	low	35		0,6			1		1		3	10		30		avg	++
GCFR	100	100	no	1990	?	?avg?	low	45		0			0			0			0			avg	++
OTHERS										15			15			15			15				
SUM										26			55			180			350				
Fusion	50 %	?	no	no	10 000	?	?	45		0			0			0			0		100 %	very high	+

Chapter 4 : RENEWABLE ENERGY RESOURCES (SOLAR, WIND, HYDRO, GEO)

§ 41 Solar Energy

The average solar energy influx in Europe is equivalent to 1 GW on a 7 km^2 area. (Note in this context that:1 GWyr is roughly equivalent to 1 Miotec). Thus, assuming a conversion efficiency of 10%, the solar energy equivalent to the present energy consumption of the Community could be taken from a surface of about 90.000 km^2 or roughly 6% of the Community's ground surface.

To produce 1 GWe (equivalent to burning about 7,000 t coal/d), an area of about 10 km^2 would be needed in the most suitable regions of the EC (e.g., in the Pyrenees), whereas in northern regions a 3 to 5 times larger area would be necessary due to smaller solar influx, smaller temperatures achieved and smaller conversion efficiency.

If bio-conversion by means of trees or fast growing plants (see below) is used to provide energy, the corresponding area for central Europe would be about 3,000 km^2 for conventional trees (0.25% efficiency). This area could be reduced for faster growing plants with a maximum efficiency of 3% to 250 km^2.

In principle, there are no technical barriers to solar energy conversion. Solar heat can be absorbed, stored and used as low-temperature heat, e.g., for habitat purposes. Costs for development and investments are low, since the distribution system is normally in situ and the heat absorbers could easily be coupled to it. A prototype solar house in the neighborhood of Metz (France) has economized 65% of its heating fuel by this procedure.

In "solar farms" solar heat can be transformed into high-temperature heat which is suitable for electricity generation. For this purpose, sophisticated and delicate devices are needed (e.g., selective surfaces). Serious studies of promising alternatives to known components seem necessary prior to construction of pilot plants. With an operating temperature of around 500^0 C, the efficiency of conversion into electricity would be acceptable. Obviously, the large investments involved would best pay in regions of considerable above-average solar influx, rare within the Community. Besides, the problem of storage and transport of energy seems predominant considering the amounts of energy involved.

On-ground photovoltaic devices for direct production of electricity: Although semiconductor technology is proven, there are still two orders of magnitude in price to be reduced in order to be competitive. This may hopefully be expected around 199o. A further bottle-neck probably exists in the capacity of the semi-conductor industry.

The application of such devices in space presents the advantage of permanent and higher solar influx (together a factor of 1o). However, the formidable problem of station-building in space by means of space shuttle transport and energy transmission by means of micro-waves remains to be solved. Costs will be very high, indeed, and the project may, if ever realized, be performed by the U. S. A. only. The impact of micro-meteorites on the performance of the photo devices needs further consideration.

Biological conversion (direct carbohydrate production). This renewable energy source is strongly dependent on climatic conditions (solar influx, heat, moisture) and on the type of plants considered. Even if so-called C_4+plants, like corn or sugar cane , having an accelerated carbohydrate production, are cultivated, the solar energy transformation efficiency will in practice be around 2% only. For other plants of slow growth and turnover, this figure may drop by a factor of 1o.

Algae production may attain a higher efficiency, but the quantities involved will necessarily be small. In principle, biological conversion may also lead to the production of hydrogen. It is difficult to judge this impact, but it is probably small for an overall energy balance.

Controlled forestry could be used to produce methanol. Estimates show that about 1o,ooo cars could be provided with fuel from a conventional forest of 4o km^2 size. The cost would not be prohibitive. Cutting, lumbering, transportation and drying of the wood would contribute with about 5 - 7 mills/kWh.

The merits of the bio-conversion system consist in its relatively small investment costs, an advantage in times when large amounts of money are needed for developing and installing other energy producing devices. That could compensate the relatively large running costs. In contrast, thermal or photovoltaic devices need at least 1o times higher investment costs but no fuel costs.

+using the C_4-dicarboxylic acid photosynthesis cycle

3

General Considerations:

A large-scale use of solar energy is tempting (also from the antipollution point of view). However (especially as compared to nuclear energy), it raises problems like

- high and still largely unknown investment costs,
- need of large and suitable surfaces,
- need of large energy storage capacities, probably leading to the use of large amounts of coal to allow the final storage of solar energy in form of CH-compounds.
- a considerable development time, which alone prohibits neglecting the introduction of nuclear fission reactors.

§ 42 Wind energy. The energy contained in air movements around the world is considerable, but difficult to transform. Wind energy is also available in regions where solar energy is not abundant. Its potential is essential. It has been calculated, e.g., that tall isolated buildings may cover all their energy requirements from wind energy installations.

There are no technical problems: wind-mills have been known for a long time. Of course, wind energy in a more pronounced way entails the same problems as solar energy, viz., those of storage, transport and vast areas to be covered.

Although large-scale on-land application is considered for the U.S.A. and USSR (in the latter case 6oo.ooo generators with a total power of 12o GW), the need for surface areas is enormous and the application therefore limited to large unpopulated areas and thus unlikely for Europe.

Off-shore use on a smaller scale and on artificial islands has been considered in The Netherlands but deserves further study as to environmental impact, siting, costs and storage.

§ 43 Water energy. All five methods mentioned (see Table III)of using water as an energy source are feasible, but only a small development potential seems to exist for tidal energy (high investment costs, only few suitable sites) and wave energy or mechanical energy of sea currents (high development and investment costs).

A bigger potential exists for using thermal gradients in sea water. Theoretically, an essential percentage of the EC energy demand could be covered. Problems include storage of energy (hydrogen !) and corrosion in sea water. The latter will probably determine the otherwise small operational costs.

Besides, sufficient temperature gradients and water currents have still to be mapped in the EC.

§ 44 Geothermal energy appears in three major forms: dry steam, wet steam and hot water, hot dry rock (as anomaly in shallow depth). The potential is difficult to assess (Larderello plant near Pisa 39o MWe). Problems exist in the frequently high salt content of the emitted water, in emission of noxious gases as by-products, and in noise disturbances.

The extraction of geothermal energy in the absence of hot spots does not seem promising.

Table II: Solar Energy

Energy Source	% Chance of success	Feasibility	Demonstration scale	Industrial scale	Development cost to industrial scale	Investment cost uc/kW	Operational cost *	% Thermal efficiency	Relation value : Energie production 1972 (Europe) = 1260 Mtec — Mtce/yr Energy Output: 1975 min.	1975 max.	1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	asymptote upper value : potential lower value : possible	Safety %	Environmental impact
Habitat	100	yes	1972	1975	low	100-300	6	40	-	-		30		75		150	possible 200	100	none
Electricity product. on ground	100	yes	1980	1985	high	1500	30	30		-		-		100		150	1500 (pot)/300	industrial	climatic impact with very large stations
Electricity product. in space	50	-	1990	2000	very high		40	11		-		-		-		-		100	none
Photovoltaic devices	100	yes	1950	1980	high	1000	20	15		-		-		-		30	1500/400	100	none
Biological conversion	100	yes	yes	-	?	-	5	2		-		-		-		-		100	none

* mils/kWh

Remark : Tables II and III by their nature more speculative than Table I

Table III : Wind energy, water energy, and geothermal ene

	Energy Source	Chance of success	Feasibility	Demonstration scale	Industrial scale	Development cost to industrial scale	Investment cost	Operational cost	Overall efficiency %	Relative Energy Output 1975 min.	1975 max.	1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	asymptote	Safety	Environmental Impact
1)	wind	100	yes	yes	yes a)	low	50–200 b) $/kW	very low	50									potential high	high	unknown, may be important
	a) if decision has been taken																			
	b) plus either essential costs for land or costs for construction of islands (presently unknown) as well as additive costs for storage (e.g. electrolytic cells and pipe lines)																			
2)	water																			
	Hydroelectr.	practically exhausted																5 %	-	none
	tidal	100	yes	yes	yes		high			only few suitable sites								small (<1%)	100	"
	waves	100	yes	yes	---	---	very high	low d)	low	very unlikely								very small	100	"
	currents	100	yes	---	---	---	high	" d)	"	unlikely								" "	100	"
	thermal gradient	100	100	yes	(1990 H_2)	high	high	" d)	2									considerable	100	unknown
	d) depends on so-far unknown corrosion properties																			
3)	geothermal																			
	steam	100	yes	yes	yes	modest	800$ kW(e)	very low	ca. 20	340 kW_{th}								small	100	acceptable
	hot rocks	100	yes	1975	no	high	high	low	"									small	high	acceptable
	e) in favorable cases (dry steam)																			

Chapter 5 : ENERGY CONVERSION, STORAGE, AND TRANSMISSION

Energy Conversion

As new energy conversion devices which still have a considerable development potential, and a large field of application, gas turbines have been treated in Chapter 1. § 13.

§ 51 Another modern device of fundamentally high promise is the magneto-hydrodynamic energy conversion from hot gas to electricity. In principle, there are two possibilities:
Closed-cycle MHD topping devices for nuclear reactor stations. Here, very high reactor gas outlet temperatures are needed; related reactor technology is not yet developed, thus there is no chance of success in the medium-term and only little chance up to the year 2000.

Open-cycle MHD topping for fossil power stations. Although a pilot plant is already in operation in the USSR with an operating power of 4 MWe with continuous runs for several hours, a larger investment in this development line seems only to be motivated if the installation of a large number of fossil fuel electricity generating plants is considered for the years 1990 ff.

It should not be forgotten that most of the admittedly considerable energy savings from MHD devices can also be obtained with gas turbines operating at lower gas temperatures and probably with lesser development problems, especially with nuclear power stations.

Less advertized (and suitable for large-scale energy conversion) have been thermionic systems. The sodium converter in principle offers itself for LMFBR use.

§ 52 Fuel Cells

Fuel cells are considered highly efficient energy conversion devices, not dependent on the Carnot cycle. 1oo% efficiency should be obtainable with an ideal electro-chemical fuel conversion system. In practice only 5o - 6o% have been reached at full charge. This figure, still to be improved, is higher by a factor 2 - 3 than that of classical heat engines. Most experience on fuel cells was gained by special application projects (space), where reliability and high energy output have been the dominant factors, but economic considerations played a minor role. Power densities of 1oo - 15o W/kg have been obtained with special fuel combinations such as hydrazine/hydrogen peroxide or hydrogen/oxygen, using Pt catalysts (7o - 1oo mg/KW). Capital investments of $ 8oo/kW might be reduced by a factor of 2 by mass fabrication.

Platinum catalysts are expensive, resources are limited. R + D efforts for substitution of noble metal catalysts (utilizing, e.g., Raney - nickel, tungsten carbide, iron phosphides, and others) led to a decrease in power density.

A promising way to completely avoid catalysts are fuel cells operating at high temperatures (6oo - 8oo ^{o}C), which might be suitable for stationary power generation by small to intermediate-size power plants (2o KW - 5o MW) (specially for remote sited areas), where high-temperature operation would not constitute a major problem. A further advantage is their ability to burn hydrocarbons, such as natural gas, CH_4 or even water gas (CO/H_2 mixtures). However, high-temperature fuel cells are a second generation development due to inherent material problems (solid electrolytes of sufficiently high conductivity, metallic - ceramic seals, electrodes and connections, stable at high temperatures and in oxidizing media). Another field of application is the transport sector (motor cars, trucks, electric locomotives) where considerable savings of oil-based primary energy could be realized, due to the high transformation efficiency in respecting environmental demands (no noise emission, clean off-gases). Here low-temperature fuel cells, fuelled with methanol would be the most suitable. They are, however, less advanced than other low-temperature types mentioned above. Further R + D effort is necessary to increase the power density (actually about 7o W/kg) by a factor of 1o to make it comparable to mobile combustion engines.

Actually, fuel cell research activities are spread over the Community (about 1o industrial firms and a comparable number of university activities). A Community coordinated basic research effort, mainly in the materials field, will be necessary in order to achieve a major breakthrough during the next decade. Under these conditions, a highly efficient energy-saving mass transport system based on fuel cells could be envisaged at the end of the century, saving about one third of the fuel consumption for transport purposes, and solving environmental problems at the same time.

§ 521 The Stirling Engine

The Stirling engine, based on a relatively old invention, has been reconsidered during the last 1o years as a possible contribution to environmental problems. As compared to classical internal combustion engines, its efficiency is remarkably higher (of the order of 4o%). Its main characteristics are

- external combustion, easily controlled and not bound to a special type of fuel,
- high torque (typically 5o mkp at 3oo rpm for a 1oo HP engine).

In spite of the higher construction cost, it can be considered a challenging alternative to large Diesel engines, e.g., for trucks and ship propulsion. No mass production of Stirling engines exists yet, although their technical feasibility has been proven; it can be expected that a noticeable cost reduction will result from mass fabrication.

§ 53 Hydrogen

The "hydrogen society" has been amply discussed during the last years. First of all, it should be stressed that hydrogen is no primary energy source, but has to be produced by transformation of primary energy. Its advantage is mainly in the field of easy storage and transportation and of substitution of hydrocarbons. Besides, its use contributes strongly to the solution of the pollution problems.

A large-scale production of hydrogen depends on the existence of large-scale cheap nuclear energy. The transformation of nuclear energy to hydrogen energy ought to use water as starting material.

Hydrogen can be produced by electrolysis which means an overall conversion factor of about 3o% in assuming an efficiency of the electricity generation of 4o% and of the electrolysis of 75%. Thus, energy resources would be strained. The process can be introduced on a large scale only when cheap nuclear energy is largely available. Such conditions would allow a hydrogen cost of 1o - 12 mils. per Mcal, which means competitivity with heat from fossil fuel. Electrolysis of water vapor at 1ooo^{o}C may still be better.

The idea to produce hydrogen by chemical cycles in order to obtain an overall efficiency of 5o% and more is very attractive. Several chemical cycles have been investigated on the laboratory scale, but none can already be safely assumed to be put into large-scale industrial operation. It seems of utmost importance to make the best choice of one or a few chemical cycles and to try their industrial realization as soon as possible. Large investment costs for the chemical plants can probably not be avoided.

Direct thermal splitting without chemical cycle necessitates temperatures well above 2ooo^{o} C, and although feasible in principle, has hardly an economic potential at present.

Energy Storage

It should be indicated that we look at the problem of energy storage not as a question of bunkering and keeping reserves, but as a means to increase efficiency of power plants by not wasting excess energy over a limited period of time. In fact, one might use the term "energy buffering".

§ 54 Hydrogen. A very convenient means of energy storage which even could use the facilities of town gas. The comparison ought to be made with pumped hydro-electric storage.

§ 55 Energy Storage by Secondary Batteries

High-energy and high-power density storage batteries are under development in the U.S.A., Japan and Europe. Applications foreseen are electric city cars as well as energy storage in large power plants (energy buffering)

For electric cars substantial energy savings are not achieved, as electricity charged into these batteries is obtained only with an overall efficiency of 35%, which, after storage and transformation losses, leads to an overall efficiency comparable to classical combustion engines. However, such type vehicles based on the present stage of development of storage batteries, can be realized earlier than fuel cell powered cars. On the other hand, electric motor and electronic power control have to be developed for both types, which makes the storage battery-driven electric car a valuable preliminary step. For sufficient operation range of battery-driven cars (about 3oo km at constant speed of 1oo km/h) substantially higher (factor 2o) power and energy densities than those of the heavy lead accumulators, are necessary. Two types of alternative solutions are under investigation in different countries:

- metal - air batteries ($Fe\text{-}O_2$, $Zn\text{-}O_2$) working at low temperatures, and
- those based on high-temperature systems such as Na/S, Li/S, Li/Se and Li/Cl_2.

Here, chlorine may be introduced in the form of chlorides, unstable at high temperatures, such as $CuCl_2$, $CdCl_2$, $NiCl_2$. Presently, power densities of about 5o W/kg have been reached for the low-temperature types and about 1oo W/kg for the high-temperature cells, the latter posing more development problems, especially on the high-temperature materials side. About 5 years of R + D are foreseen for a full-scale development of a commercial storage battery applicable to vehicle propulsion. Even after the development of fuel cells for the same purpose, storage batteries would still be useful as peak power storage devices as in a hybrid car, where fuel cells would be combined with a storage battery, the latter for high peak currents during start and acceleration. Besides, a recuperation of braking energy in the storage battery is feasible.

For large stationary power storage, high-temperature batteries with molten salt electrolytes look quite promising.

§ 56 Flywheels. A very modern device for energy storage are ameliorated flywheels. Optimistic assumptions are that 1o MWh can be stored on a surface of 36 m^2, whereas a hydro-electric pumping plant would need 3oo times as much surface. The maximum energy out-flux of such a storage is estimated at 3 MW. The investment costs are assumed to be lower than those of hydro-electric pumping storage plants of similar capacity. Evidently, such ambitious projects are intimately connected with advances in the research of materials.

Energy Transmission

§ 57 Energy transport by hydrogen in pipelines is approximately 1o times cheaper than by electric lines, although energy saving is negligible. Economic advantage of hydrogen transport is more pronounced for distances of some 1oo km.

Another advantage of hydrogen transport is the transfer of nuclear (or other) energy from remote regions, e.g., from off-shore power parks to the consumption places.

§ 58 In the field of electricity transport, there are no cheap alternatives yet to overhead lines. Therefore, at present savings in transmission costs and energy could only be made by installing power stations close to the consumers and vice versa. Thus, the siting strategy has to be carefully examined.

§ 59 In the long run, continued development of more efficient high-power cables is necessary, especially for application where high-voltage overhead lines are not suitable. Supra-conducting cables offer a good prospect for carrying very large amounts of power (about $1o^4$ MVA in one single cable).

§ 591 Waste heat from power plants could be used for urban heating over a distance of 5o km with a loss of about 1% (circuit with a tube diameter of 3 m, a pumping speed of 2 m/sec, and a temperature drop of $4o^0$C). Even if less stringent demands are made, e.g., if a 1o% heat loss is tolerated on 3o km, a price of 1.5 UC per Gcal transported might still be reached. In this way, waste heat could be used for heating in winter, whereas storage of the heat in summer is not yet secured.

Recent development in the technology of well insulated pressure tubes would allow to pump hot water over long distances with tolerable losses. With heat losses of 5o W/m^2, water, heated by solar energy to $35o^0$C at a pressure of 2oo atm,could be transported from the Sahara to Europe. This does not seem to be a realistic proposal. Use in connection with solar farms in suitable regions within Europe has the drawback that large amounts of sand as an efficient and cheap heat storage medium are not available on the best solar mountainous regions and cannot be substituted by other storage media at acceptable prices.

Table IV : Fuel cells Hydrogen production and MHD topping devices

	Energy Source	Chance of success	Feasibility	Demonstration scale	Industrial scale	Development cost to industrial scale M $	Investment cost $/kW	Operational cost	Thermal efficiency in %	Possible Transformation Capacity (or Saving) in Mtec/year 1975 min.	1975 max.	1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	asymptote	Safety	Environmental Impact
Fuel cells	Fuel cells for stationary power	yes	yes	yes	1990	250	400	avg	50 to 65	0		0		0		?			avg	no
	for mobile power	yes	yes	yes	1990	150	100	high	30-40%	0		0		0		a)			"	no
Hydrogen	Hydrogen product. from nucl.energy electrolysis	yes	yes	yes	yes	low	b) 150	0,6mil	c) 70-85%	o	o	1		20		60		unlimited d)	avg	no
	chemical cycles	yes	yes	no	no	?	high		50	o	o	?						?	avg	?

a) If 50% of the cars are powered with fuel cells, 25% or the energy consumption of cars will be saved

b) For large electrolysis plant add the cost of the related nuclear power station (400 $/kW)
c) For electrolysis; hence overal plant efficiency 20-30%
d) If Breeders or fusion reactors available

	Energy Source	Chance of success	Feasibility	Demonstration scale	Industrial scale	Development cost to industrial scale M $	Investment cost $/kW	Operational cost	Thermal efficiency in %	1975 min.	1975 max.	1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	asymptote	Safety	Environmental Impact
MHD	Closed cycle for nuclear plants	yes	a) yes	no	no	?	avg	avg	15 b)	0		0		0		0		?	good	no
	open cycle for fossile power plants	yes	yes	c) yes	1990	?	avg	avg	b) 15-20	0		0		0			1	80 d)	good	yes

a) Laboratory scale; and only for short operation time (hours)
b) To be added to the conventional plant efficiency of 35% (for nuclear plants) or 40 % (for fossile plants)
c) In USSR
d) Supposing 400 Mtec/yr installed with fossile fuel plants

Table V : Storage and Transport

Energy Source	Scientific feasibility	Technological feasibility	Demonstration scale	Industrial scale	Development cost to industrial scale	Investment cost	Operational cost	Thermal efficiency	Energy Saving(s) 1975 min.	1975 max.	1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	asymptote	Safety problem	Environmental Impact
Advanced Accumulators	yes	yes	yes	1975	?	?	?	80%	a) o	o	o	o		6 % b)		20 % b)		yes	no
Supráconductivity	yes	yes	(c) yes	no	?	d)	?	97,5%	o	o	o	o	o	o	o	o	?	no	no

a) Accumulator > 90 %, motor control 90 %, hence total efficiency of the car 80 %
b) Of the total energy consumption of cars
c) in laboratory
d) 250 $ /MVA. Mile for a capacity of 6400 MVA

Preliminary Conclusions of Mark I

The findings supported by the first rough analysis contained in this draft, are partly trivial and well known to the public:

1. The immediate reaction to diminishing oil imports are those of energy savings and reglementations. The next step in time is efficiency increase and utilization of otherwise wasted energy.

2. The next step is to increase domestic production, which in the case of the European Community means essentially off-shore drilling for oil and gas and intensified coal mining.

3. The only larger new energy source firmly established at present is that of nuclear fission energy, and the construction of a large number of efficient nuclear reactors has to be decided on as soon as ever possible together with the choice of optimum siting (power parks).

4. All other R + D activities will lead either to minor or later improvements, but must, nevertheless, also be started immediately in order to decrease the potential energy imports gap's impact in size and time.

Additional Conclusions of Mark II

5. There is no evidence for a sufficiently coordinated adequate R + D effort in the European Community.

6. The normal priority criteria (as used in the US report "The Nation's Energy Future", December 1, 1973) are not sufficient because the relative value of alternative energy systems (and strategies) and the relative use of sources or processes within the system have to be considered.

7. A global financial assessment of the European Energy Development costs seems indicated in order to define clearly the financial boundary conditions at an early date, which may influence or limit the possible choices.

ENERGY PROGRAM GROUP

Main R + D Impacts

§ 1 It might be useful to define the notion of "R + D Impact". From the point of view of society, an impact is asked for from R + D to relieve the energy crisis. R + D should contribute to close the real or possible gap as soon and as efficiently as possible. This must be the main criterion for proposing R + D actions.

On the other hand, the crisis will have its impact on the redistribution and reactivation of running research activities and the initiation of new ones. It is easy to see that both impacts are interconnected.

§ 2 In order to approximately quantify and to list R + D actions according to priority and their impact on the overall energy situation with special regard to the Community's supply, certain estimates have to be made as to the relative contribution in time of the various energy carriers.

§ 3 In Table VI, we limit ourselves to 9 major actions which together may constitute the largest part of the overall R + D financial impact.

In order to give priority classification, we have to use three different measures, viz.,
- impact on the energy situation, integrated until the end of the century,
- impact as to the substitution of the special qualities of oil (fluidity, use for petrochemistry and transportation, etc.),
- long-term impact.

In Table VII, a list is given of studies, which may result in R + D activities.

(4)

SURVEY OF MAIN R + D ACTIVITIES

§	Title of Activity	A Short-term Impact	B Oil Substitutional Impact	C Long-term Impact	Relative Funding during next 5 years
13	Gas turbines	xx	-	xx	3.5
23	Coal gasification (including organic waste utilization)	-	xxx	-	1o
32	Nuclear reactors				
	LWR safety and fuel element improvement	xxx	-	-	15
	HTGR fuel development and fuel cycle optimization	x	-	xx	17.5
	LMFBR advanced fuel, safety, fuel cycle, components	x	-	xxx	25
35	Thermonuclear fusion, magnetic confinement, laser fusion, material development	-	-	xxxx	1o
41	Solar energy for habitat and by means of photo-cells	xx	-	xxx	2.5
52	Fuel cells	xx	-	xx	2.5
53/55	Hydrogen production; storage batteries; use for transportation, etc.	-	xx	-	5.o

Legend:
x) Impact lower than 1%)
xx) " between 1 - 5%) of the overall energy supply for A and B, integrated until the end of
xxx) " " 5 -1o%) the century, for C beyond the year 2ooo.
xxxx) " above 1o%)

Table VII

LIST OF STUDIES

Conservation:

§ 14 Assessment of potential of heat pumps
15 Study on Mansholt proposal
16 Power parks

Non-imported Fossil Fuel:

§ 21 Prospection and resources assessment for oil
23 Assessment for coal

Nuclear Fission Energy:

§ 31 Evaluation of irradiation risks at low dose,
" " radiological consequences of increased growth rate of nuclear installations in the EC
Standardization of EC nuclear power stations
Plant decommissioning (consequences + procedures)
Thermal pollution
Study of mixed cycle (Th, U, Pu)
33 Reactor strategies studies
331 Nuclear propulsion assessment

Solar Energy:

§ 41 Technico-economic evaluation of large-scale electricity production on ground
Study of impact on bio-conversion (forests and C_4 plants, etc.)

Wind Energy:

§ 42 Study of environmental impact
Cost analysis (siting of artificial islands, energy storage and transport)

Water Energy:

§ 43 Study and cost analysis of use of temperature gradients in sea water (siting, materials problems)

Geothermal Energy:

§ 44 Mapping and inventory of hot springs and heat anomalies (hot rocks) in EC. Evaluation of their potential.

Energy Conversion, Storage and Transmission

§ 52 Fuel cell assessment for stationary and mobile power
53 Economic assessment of hydrogen production by chemical cycles
55 Economic assessment of secondary batteries
591 " " " latent heat and hot water storage

Energy units and conversion factors

	Wsec, J	BTU	kcal	kWh	Gcal	tec+
Wsec, J	1	9.5×10^{-4}	2.39×10^{-4}	2.77×10^{-7}	2.39×10^{-10}	3.4×10^{-11}
BTU	1.05×10^{3}	1	0.252	2.93×10^{-4}	2.52×10^{-7}	3.6×10^{-8}
kcal	4.18×10^{3}	3.97	1	1.16×10^{-3}	10^{-6}	$1.43.10^{-7}$
kWh	3.6×10^{6}	3.41×10^{3}	8.62×10^{2}	1	8.62×10^{-4}	1.23×10^{-4}
Gcal	4.2×10^{9}	3.97×10^{6}	10^{6}	1.16×10^{3}	1	0.143
tec+	2.93×10^{10}	2.78×10^{7}	7×10^{6}	8.12×10^{3}	7	1

+ for coal of 7 kcal/g (as in Germany)

Technical energy units

	Miobarrel	Miotec	$GWyr_{th}$	Gm^3(N.G.)	mQ
Miobarrel	1	0.16	0.15	0.14	4.4×10^{-3}
Miotec	6.3	1	0.94	0.88	2.8×10^{-2}
$GWyr_{th}$	6.7	1.06	1	0.94	3×10^{-2}
Gm^3(N.G.)	7.2	1.14	1.07	1	3.2×10^{-2}
mQ	2.26×10^{2}	36	33.6	31.5	1

1Q = 10^{18} BTU (1 quintillion BTU)

1 barrel = 159l = 42 US gallons
N.G. = natural gas

power units

	Miotec/yr	$GW_{therm.}$	$Mioft^3$/d (N.G.)	Miobarrel/d
Miotec/yr	1	0.94	9×10^{-2}	1.7×10^{-2}
$GW_{therm.}$	1.06	1	9.6×10^{-2}	1.8×10^{-2}
$Mioft^3$/d (N.G.)	11	10.4	1	0.19
Miobarrel/d	58	54	5.2	1

Energy content of different fuels (kcal/g)

coal	6 - 7	oil	9.5
lignite	3 - 4	gasoline	10.6
wood (dry)	3.6	methanol	4.8
hydrogen	28.7		
methan	11.9		
CO	2.4		

SWU — Separation work unit

$SWU = PV(x_p) + TV(x_t) - FV(x_f)$

where P, T and F are the amounts of uranium in the plant product (desired enriched uranium), tails (depleted uranium), and feed (e.g. natural uranium). V(x) is a value function representing the "value" of one unit of uranium (not to be confused with price or cost of material) defined by

$$V(x) = (2x-1)\ \ln\left(\frac{x}{1-x}\right)$$

Typical needs for installation of first cores :
LWR 216 t SWU/GW_e
THTR 317 t SWU/GW_e.
For reloading, the two types of reactors need 130 and 88 t SWU/GWyr, respectively.

Prices for fuels

	$/Gcal	
coal	3-6	20(US,UK) to 40 $ (D)/to
oil	7,5	8 $ average price, 11.65 $ posted price/barrel
gas	1.4-1.6	
uranium	1.3×10^{-3}	25 to 30 $/kg U in UF_6

Storage of Electrical Energy

	GWh	MW	$/kW	η(%) efficiency	Technic.* feasib.	gm/MWh	life-time (yr)
hydro pump	~1	500	~ 500	65	3	1000	> 50
batteries Pb	10^{-6}	10^{-4}	30	75	3	100	2
batteries adv.	5×10^{-6}	$\sim 10^{-3}$	?	70	2	< 100	
flywheels	0.01	3	110	85	1	4	> 50
compressed air	~1	~100	?	80	1	under-ground	long
supra-cond. coilds	~0.1	~0.01	?	98	1	~100	?
H_2/fuel cells			~ 400	50–65	2		

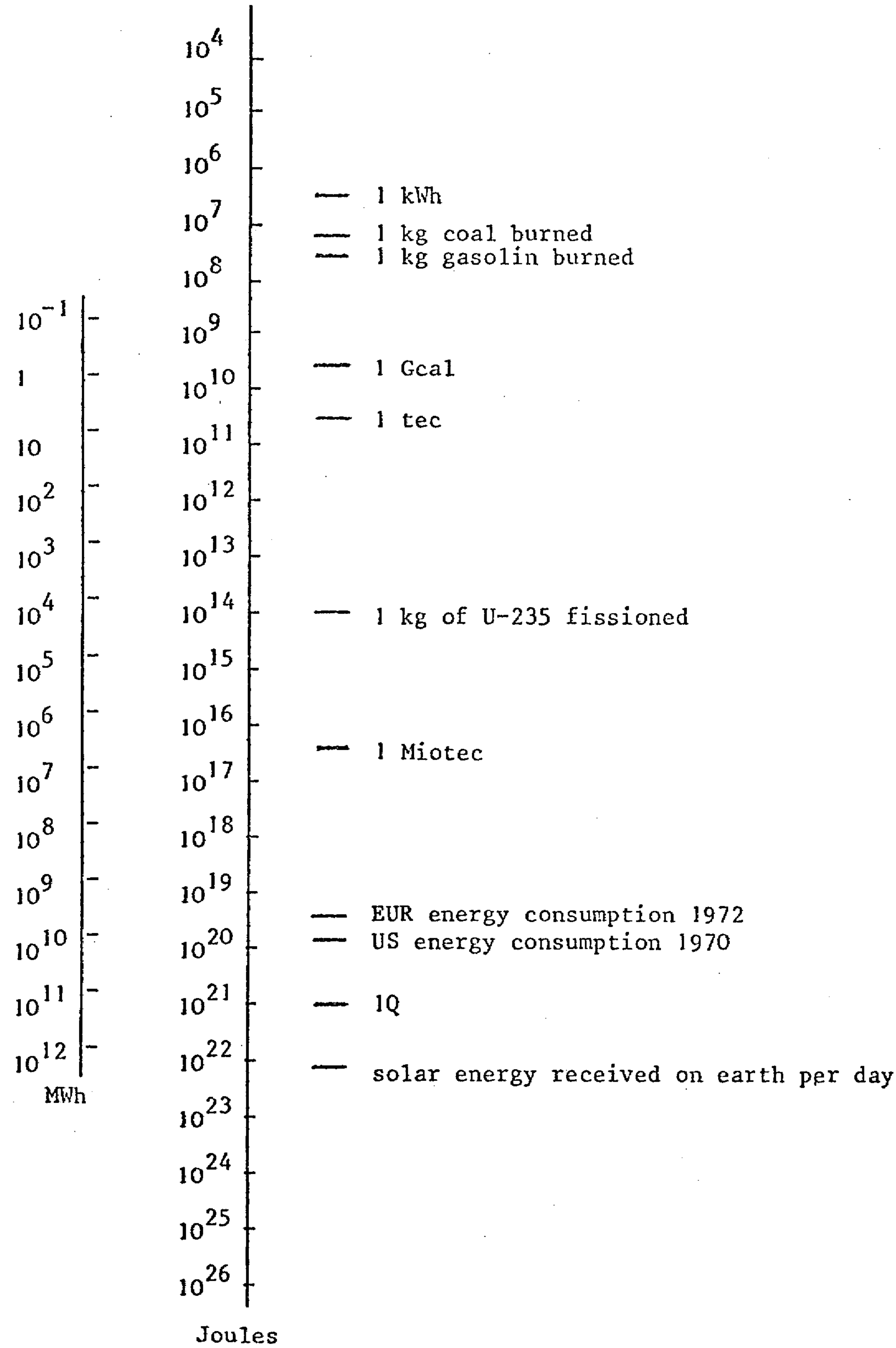
* 1 = development stage, 2 = demonstration stage 3 = existant

Storage of Thermal Energy

		T(°C)	per MWd weight(to)	per MWd vol.(m^3)	
latent heat,	LiH	680	60	70	(too high T for solar)
	NaOH	320	1200	600	
	$LiNO_3$	250	700	300	
warm water		90	240	240	

Specific energy content for typical storage media

	kWh/kg
LiF	0.5
battery,adv.	0.07
Pb	0.04
press. gas	0.02
fly wheel	0.05
hydrogen	33
gasolin	12



Orders of magnitude of characteristic energy amounts.

ENERGY R + D in U. S. A. and E.C.

A Comparison

	Unit	U. S. A.	E. C.
Total Energy Consumption	Miotec	26oo	126o
Imported Energy	%	15.o	6o.1
Domestic production			
Oil and gas	%	62.8	12.6
Coal	%	17.3	22.5
Nuclear +)	%	o.9	1.6
Solar, geo, hydro	%	4.o	3.2

Table VIII: Energy supplies and dependency of imported fossil fuel for USA and EC (year 1972)

+) Forecast of development of nuclear power in U.S.A. and E.C.

Nuclear power installed in GWe	U.S.A.	E.C.
1972	9	8
1975	(5o)	25
198o	1o5 - 2oo	55
1985	18o - 3oo	14o - 26o

	U.S.A.	E.C.
Solar radiation	big areas with ≈ 2ooo kWh/yr·m²	≤ 145o kWh/yr·m²
Sea water	Gulf stream	Mediterranean without comparable currents

§ 1. Table VIII shows some essential differences between the USA and the EC as far as energy supplies and dependency on imported fossil fuel is concerned. Besides, it is reminded that industry participation in research funding is larger in the US than in the E.C.
Prominent features of this Table are

- a much lesser dependency on imported energy for the USA,
- a much higher energy consumption (which a priori allows for more possibilities of economy and energy conservation),
- the better supply in potential new energy sources,
- the higher degree of advancement in the introduction of nuclear energy available or being installed before 1985.

In fact, the only point of advantage for the EC could be a higher degree of purity for coal to be extracted, however with considerably higher mining costs because of the necessity to go deep underground (1ooo m).

§ 2. These facts should be kept in mind when regarding the US energy development program because

- the urgency is in nearly all regards larger for the EC,
- the possibilities are generally less,
- a unified organization, suitable for a crash program is practically non-existent.

§ 3. As far as US international cooperation in general is concerned, the criteria are not only

- the impact on the domestic priorities, but also
- the existence of useful foreign technology,
- the time lag for commercial utility,
- the lack of barriers to information exchange and
- the opportunity to expand existing cooperation.

§ 4. In this regard, three groups have been defined in the USAEC Report to the President:

High priority: coal technology, energy conservation and environmental studies, resource assessment, transportation systems, and geothermal energy

Medium priority: conversion technology, fuel transport, hydrogen economy, reactor safety, fusion and solar energy,

whereas all other nuclear activities are in the low priority group, as well as electrical transmission, energy storage, hydro energy, wind and tidal power and oil and gas technology (quite in contrast to coal technology).

§ 5. One may assume that this priority grouping uses, however, the usefulness for the US energy deficit as the primary criterion. In order to knit the network of international cooperation also from the other side, the bilateral or multilateral usefulness has to be considered, which includes the mirror image, at least inasmuch as useful American technology is existing and an impact on the energy deficit of the EC can be expected.

Some specific points

§ 6. When discussing energy conservation, it must be realized that the distribution on the various sectors is different in the U.S., industry uses 40%, space heating and air conditioning 25% and transportation 25%, considerably more than in Europe. The main gains are expected from the amelioration of conversion techniques and also from ameliorations in the transport sector, where even inefficient automotive power trains are mentioned. (Obviously, automatic transmissions are hardly acceptable from this point of view).

In spite of the smaller impact of the transportation energy consumption in the EC, liquified gas and metallic-bound hydrogen for internal combustion as well as methyl alcohol (for both internal combustion and fuel cells) have to be considered besides the immediately accessible sector of efficiency increase in existing hydrocarbon internal combustion engines.

In the conservation field, the identification and quantification of energy conserving practices and processes in the whole of the economy is urgent in both USA and EC.

§ 7. The development of a model for the energy system is worthwhile for both US and EC conditions. EC has specific experience to contribute as a valuable partner.

§ 8. Special interest in coal gasification is also due to the fact that 6o% of the US coal has too high a sulfur content according to present emmission standards; this is also an EC activity based on long industrial experience.

§ 9. The development of combined cycle technology , as far as gas turbines are concerned, is to be strongly advocated for EC as well as US conditions, whereas potassium topping cycles and magneto-hydrodynamics cannot contribute much more than the gas turbines, which we ought to place the main effort upon under European conditions.

§ 1o. Comparatively straight-forward methods to increase domestic production of energy carriers (fossil) amount, in the case of the EC, essentially to three things:

- off-shore drilling,
- deeper or new coal mines and
- only to a smaller extent oil shale utilization technology to be applied to own or foreign fields.

§ 11. In the nuclear field, safety research and demonstrations are still an important necessity for fast introduction on a large scale of nuclear fission reactors both in the US and EC, especially for LWR and LMFBR. Equally apply the necessities for HTGR fuel reprocessing, LMFBR advanced fuel for acceptable doubling times, etc.

US Priorities in Energy R + D (as discussed in the Report to the President, December 1, 1973, "The Nation's Energy Future")

This report culminates in the suggested distribution of 1o Bio. $ to be spent for R + D in the energy field during the years 1975-79 in order to reach energy independence for the U.S. A. as soon as possible. The time target was 198o, but seems to have changed to 1985. It was postulated in November 1973, well after the original directive for that report (June 29, 1973).

The report is based largely on material prepared beforehand and includes the work of 16 review panels, composed of 121 Federal employees and 282 consultants, reviewing more than 11oo specific proposals. The draft of the report was circulated to more than 1oo individuals for comments. Thus, it is a very comprehensive piece of work which, however, in some first reactions has been criticised as not constituting a clear element for further action.

As to establishing priority criteria, the following common procedure (which however neglects strategic coherence) was applied: for the R + D phase as well as for the implementation phase and the pay-off phase expected values ranging from 1 - 3 were given to each action, in some cases multiplied with weighting factors, expressing the relative importance of the criteria. Non-economic considerations were only partly considered.

With this simple method, three categories could be discerned of high medium and lower priority.

To the first group belong the following: conservation, resource assessment, oil and gas, coal and shale processing, mining coal and shale, and fission.

To the second category: conversion techniques, advanced transportation systems, energy and fuel transportation, distribution and storage.

To the last: geothermal, fusion and solar.

INVENTORY OF RESEARCH

publicly financed in EC on Non-nuclear Long-term Energy Supply, Transport, Transformation and Substitution

1. This inventory (cf. Tables in Annex) is to be considered a first sweep of the field, based on about 75 questionnaires obtained following a circular note from EC services from the respective national authorities in Belgium, France, Italy and the U.K. As far as Germany is concerned, the results given are based on information obtained from the Ministry of Research and Technology on projects directly supported.

   The information is still very incomplete, especially as far as quantitative information on budget and manpower is concerned. Nevertheless, certain conclusions can be drawn already now.

2. The most important of these conclusions is that beside the well established national and international nuclear research programs, no comparable effort has been made for alternative sources. Nearly all effort in the non-nuclear field has been initiated by other demands considered to be of higher priority up to the end of last year, such as

   - improvement of environmental conditions,
   - the need for better mass transportation systems, especially in the urban regions,
   - increase of efficiency of existing energy transformation and transportation devices and
   - last, not least, simple economical considerations, mainly concerning coal mining and utilization.

   So-called "paranuclear" research, mainly carried out in Germany and centering around the problem to reasonably utilize high-temperature heat as produced from high-temperature helium-cooled reactors, had been considered mainly under the two last mentioned aspects.

3. Only limited research has been carried out up to now, aiming at a large-scale substitution of oil as the major primary energy source within a reasonably short period of time. Nevertheless, certain activities, such as research on new means of motor car propulsion, coal gasification by nuclear or non-nuclear methods, certainly constitute a valuable starting point on which further research on a larger scale and in a more coordinated manner should be based.

4. As to the Tables in the Annex, a short explanation: As it has not been possible to give a complete and representative survey of the field, the questionnaires mentioned above being incomplete and covering only research sponsored by the respective governments, no attempt has been made to present detailed figures of budget and manpower, but only orders of magnitude are given. However, the institutions carrying out the research have been mentioned as this might be helpful in obtaining further information. All nuclear research, as far as reactor development is concerned, has been left out, as well as fusion research, as this information may be easily derived from other sources.

5. The research subjects have been divided in the following Tables into three large chapters:

1. New sources of primary energy, including utilization of nuclear heat for purposes other than electricity generation.
2. Increasing efficiency of energy transport, storage and transformation, including studies on more economic use and extraction of primary energy carriers (such as coal, oil).
3. Substitution of classical energy sources for transportation purposes.

6. As can be seen from the Tables, most of the research carried out in the different member states under consideration falls into categories 2) and 3). In the last one, a certain concentration on electric vehicles for mass transport as well as for individual motor car purposes is observed. As private industrial research efforts, e.g., those of the large motor car companies, are not contained in this surview, we feel that in this field, where much uncoordinated fundamental research has been done already now, a coordination and concentration of efforts seems most urgent in order to arrive at a break-through within the next years.

Annexes

3/18/74

Annex

LIST OF SYMBOLS USED IN THE FOLLOWING TABLES

Chapters

1 New sources of primary energy, including application of nuclear power to purposes other than electricity generation.

2 Increasing efficiency of utilization of classical energy sources, including electricity storage and transport.

3 Substitution of classical energy sources, mainly in the transportation sector.

Type of Research

A Fundamental research

B Construction of prototypes, technical scale demonstrations

C Improvement of existing equipment and/or methods

Manpower Involved

I Limited activity, mainly academic research or conceptional studies, corresponding to less than lo man/a

II Larger-scale technical activity, corresponding to lo - loo man/a

Budget During Period Planned

I Less than o.1 MUC

II o.1 - 1 MUC

III Greater than 1 MUC

FEDERAL REPUBLIC OF GERMANY (Activities financed by the Ministry of Research + Technology)

Chapter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
1	Bergbauforschung Essen-Kray	Coal Gasification utilizing Nuclear Heat	no inf. avail.	72-75	II	III
	Rheinische Braunkohlenwerke AG Köln	"		72-75	II	III
2	Batelle Institut Frankfurt	New Electricity Storage Devices Na-S Accumulators	no detailed information available	73-75	I	II
	Brown-Boveri Mannheim	"		73-77	I	II
	Siemens AG München	Metal-Air Storage Batteries		70-75	I	II
	Varta AG Frankfurt	"		68-73	I	II
	Brown-Boveri Mannheim	He-Turbines for HT-Reactors		72-74	I	II
	Energieversorgg. Obernhausen	"		72-73	II	III
	Hochtemp.Reaktorbau-Köln	"		72-74	II	III
	Nukem GmbH Wolfgang	"		69-74	I	III
	TH Aachen	"		70-75	I	II
	TH Hannover	"		70-76	I	III

FEDERAL REPUBLIC OF GERMANY (Contind.)

Chapter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
	MAN München	Energy Storage by large Fly-wheel Systems.	no detailed inf.avail.	73-75	I	I
	Siemens AG München	Supraconducting Materials Research		73-75	I	II
	AEG-Telefunken Frankfurt	Supraconducting Cables		70-73	I	II
	Siemens AG München	"		70-74	I	II
2	"	Electricity Transport at very High Voltages		71-74	I	II
	"	SF_6-filled Cables for --		73-76	I	II
	DFG/Univers. Braunschweig Heidelberg	Theoretical and Tecnical Studies of Rectifiers and Control Devices for--	A, B	60-72	II	II
	DFG/Univers. Hannover Stuttgart Darmstadt Braunschweig Aachen, München	General Investigation of Insulation Problems	A	72-78	I	II
	AEG-Telefunken Frankfurt	Fuel Cells for Natural Gas-Air without Noble Metal Catalyst	A, B	69-73	I	III
	Batelle Institut Frankfurt	Cathodes for FC, acid Electrolyte without Noble Metal Catalyst	A	71-73	I	II

ERAL REPUBLIC OF GERMANY (Contind.)

pter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
	Batelle Institut Frankfurt	High Temperature Fuel Cells, Materials for electric Connections	A	71-74	I	II
	R.Bosch GmbH Stuttgart	Phtalocyanine Catalysts for Fuel Cells	A	70-73	I	I
	"	Investigations on Solid Electrolytes for H.T. Fuel Cells	A	71-73	I	I
	"	Physicochemical Investigations (Low Temp.F.C.)	A	71-73	I	II
2	Brown Boveri Mannheim	High Temp.F.C. Prototype Development (2-3 kW)	B	72-74	I	II
	Siemens AG München-Erlangen	Low Temp. F.C.(5 kW) Prototype for Natural Gas with Reforming Unit	B	68-73	I	III
	"	Investigations on Catalytic Reactions	A	70-75	I	II

ITALY

Chapter	Research Organisation	Research Subject	Type of Resesearch	Planning	Man Power involved	Budget (during period planned)
1	ENEL/Politecnico di Milano - Ist. di fisica tecn.	Geothermal Energy Systematic research of new sources Application to electricity generation	B, C	65-75	II	III
	CSM-Roma	Application of Nuclear Heat for Siderurgic Purposes Fluidized bed reduction of iron-ores	B	73-77	II	II
2	CSM-Roma	Improvement of Coke Production New Procedures for c.p. from inferior quality coal	B, C	72-77	II	III
	Italsider	"	no detailed information given ----------			
	Asgen-IMI	Supraconducting DC-Motor	A, B	71-75	I	II
	ENEL	Supraconducting Cables Design Studies	A	71-73	I	1
	CNEN/Ist.Metalli Leggeri-Novara	Supraconducting alloys, prod. methods	A	72-77	I	II
3	Asgen-IMI	Energy Saving Power Electronics for Electric Motorcar Drive	B	68-77	II	II

FRANCE

Chapter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
1	Gaz de France	Hydrogen Production utilizing Nuclear Heat	A	69-85	II	III
2	CEA/EdF	He-turbine Cycle for HT Reactors	A, B	no detailed information given		
	MDIS/Univ.de Toulouse Lab.Génie Electr.	Therma Insulation for Supraconducting Cables and other Devices	A	74-?	I	I
	EdF/Lab.Central Ind.Electrique	"	A	72-74	I	II
	EdF/Direction Etudes et Recherche	Supraconducting Materials	no detailed information given -----			
	Gaz de France	High Temperature Fuel Cells for Natural Gas	A	60-73	I	III
	EdF/CGE	ß-Alumina solid Electrolytes for ---	A	72-74	I	I
	MDIS/Lab.Central Ind.Electrique, Lab.Génie El.	Motors and Controle Devices for Electric Motorcar Drive	A	71-74	I	II
	Ist.Polytecn.de Toulouse, Lab. Electrotecnique	"	A, B	60-?	II	III
	"	"	A, B	72-74	I	II

GREAT BRITAIN

Chapter	Research Organisation	Rese ch Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
1	Electrical Research Association	Solar Cells (CdS and Si type)	- No detailed information given ----			
	Crompton-Parkinson	Energy Storage Devices (Zn-accunulators)	- No detailed information given ----			
2	Electric Research Association/UKEA	Advanced Accumulators	A	72-74	I	II
	Univ. London Dept.of Chemistry	Iron-air Accumulatotrs	A	72-75	I	I
	Oxford University Dept.of Eng.Sc. Cryogenics Lab.	Supraconducting Machines (Generators) Heat Transfer by He	A	73-76	I	I
	Electric Power Storage	Hydrogen-Oxygen Fuel Cell Batteries	A	no detailed information available		
	Shell	Methanol Fuel Cell	A	project shelved since 1970		
	Science Res.Council Univ.College Swansea Dept.Chem.Eng.	High Temperature FC with molten Organic Electrolytes	A	72-75	I	I
	Science Res.Council City Univ.London	Current Collectors for --- New Catalysts for --	A	69-74	I	I

GREAT BRITAIN (Contd)

Chapter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
3	Imperial College Dept.of El.Engin.	Linear Motors (Transverse Flux Machines)	A	72-75	I	I
	North Wales School of Engin. Science	New Forms of --	A	72-73	I	I
	Crompton-Leyland Electricars Ltd	Electrobus Prototype Constr.	B	70-73	?	II
	Nat.Res.Council/ Univ.Liverpool	Linear Motors for Vehicle drive General Theory	A	73-75	I	I
	Queen Mary College London	Design and Feasibility Studies	A	72-75	I	I
	Brighton Polytechnic. El.and Electronics Dept.	Electric Car Drive Model Construction	A	71-73	I	I

BELGIUM.

Chapter	Research Organisation	Research Subject	Type of Research	Planning	Man Power involved	Budget (during period planned)
2	CECA/Univ.Libre de Bruxelles Service Chimie Gén. et Radioactivité	Production of Organic Chemicals as by-products during Coke Formation	A	72-75	?	II
	CECA/Kempense Steenkolenmijnen et Fac.Polytec.de Mons	Improvement of automatic machines for Coal Mining	B,C	73-76	I	II
	SCK/CEN	Fuel Cells for Methanol or Hydrogen-Air	A, B	61-73	I	II
	Faculté Polytecnn. de Mons	Fuel Cell for Hydrogen-Oxygen (Prototype)	A, B	66-?	I	I
3	Evelec S.A.	Electric Motorcar Prototype Construction	B	72-75	I	II
	Fac.Polytec.de Mons	Control Circuits for --	B	73-?	I	I

EC Energy R + D , totally or in part financed by the European Commission

In the Energy R + D sector, the EC Commission is at present supporting essentially the following major activities:

A. In its own Joint Research Center (with approximate total manpower and annual budget):

1. Reactor Safety , Ispra	232	5.275 MUC
2. Advanced Pu fuels, etc.,Karlsruhe	21o	4.95o MUC
3. Hydrogen by chemical cycles, Ispra	7o	1.65 MUC
4. Solar Energy, Ispra	15	o.38 MUC

In addition, supporting studies for nuclear power plants, on Waste Disposal and Fissile Materials Control as well as system studies can be mentioned.

B. In Association Contracts (with national laboratories)

1. Thermonuclear Fusion -	138	delegated researcher -	18 MUC
2. DRAGON project	2o	" "	3.5 "

The activities A 1 - 2 and B 1 - 2 are well established, widely accepted and sufficiently controlled. A 3 and 4 are being established, but still subject of discussion, although they may constitute a crystallization point for a major break-through in the EC.
However, the potential of the JRC has not yet been fully exploited for Energy R + D. Thus, a comparatively important, but largely unoriented Materials Research activity could easily be directed in fields like: Superalloys for HT gas turbines, Oxygen conductors for HT fuel cells and molten phases secondary batteries.

Furthermore - and especially with regard to Associations - reference is made to the list of recommended studies in this document (p. 46).