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ENERGY RESEARCH AND DEVELOPMENT PROGRAMME

1979 - 1983

Contents

I. INTRODUCTION

The drastic rise in oil prices of 1973 drew attention to the finite nature of the world's fossil fuel reserves and to the potentially serious consequences of depleting these too rapidly. It highlighted the need for the nations of the world, particularly the industrialized ones, to conserve energy by using it in more economically efficient ways, if their standards of living were to be maintained.

Under these circumstances the Member States of the European Community developed way and means to conserve energy and to explore new energy resources.

To further energy conservation within the Community, two main programmes of activity have been initiated as follows :
the Rational Use of Energy (RUE) programme and the Energy research and development programme,a part of which is devoted to energy conservation.

On 17 December 1974, the Council adopted a Community action programme (COM(74)1950 final) establishing priorities and the forms and means of action required to achieve a 15% energy saving in 1985. This programme was designed to meet its objectives of bringing about a more rational use of energy by the following measures :

a. The dissemination of information to promote the idea of energy saving, to achieve a better understanding of practical ways of saving energy and to change public attitudes.

b. The introduction of legal, administrative and monetary regulations to make energy saving more attractive.

c. To catalyse the innovation of new energy saving technology by measures such as the financing of selected demonstration projects and the dissemination of the resulting information, demonstration projects being a means of exploiting the results of the Community or national R & D programmes.

ENERGY CONSERVATION

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II. THE FIRST ENERGY R & D PROGRAMME (ENERGY CONSERVATION)

On 22 August 1975, the Council adopted an energy research and development programme, one of its objectives being "energy conservation". For the implementation of this objective, 11,380 m.u.a. were assigned. The programme was to last four years and the work was to be carried out under contract.

Within this objective, the following sectors were to be included :

(a) improvement of insulation in buildings;
(b) use of heat pumps;
(c) urban transport;
(d) recovery of residual heat;
(e) recycling of materials;
(f) production of energy from waste;
(g) assessment of the specific energy consumption of various equipment, processes and techniques;
(h) development of methods of accumulating secondary energy.

At the end of the first stage of this programme the Council decided on 21 December 1976 to continue the implementation of the objective "energy conservation" without any amendment.

Members of the staff representing the Rational Use of Energy (RUE) group have participated and are currently participating in the ACPM meetings in order to secure conformity with the objectives, recommendations and regulations worked out by the RUE group.

The Commission also participate in the activities of the International Energy Agency, in particular the Working Party on Energy conservation, and examines the possibilities and the interest of Community participation in the Agency's implementing agreements.

A survey of the Community's current energy conservation R and D programme is given in the Annex I.

The Commission in its communication to the Council of 30 June 1977 on "Common Policy in the field of science and technology" stated that Energy Conservation, which is still in its initial stage, must play an important role in the short and medium term.

In the CREST's opinion (CREST/61/77 and R/5/78 (Rech 1) of 3.1.78) the Community should concentrate strongest possible efforts of R and D on "Energy Conservation", the field of which is recognized as of high importance and such as to ask for a certain number of limited single actions.

The CREST has noted the Commission's opinion on the aims of co-ordinating national R and D policies and emphazises the importance of co-ordination as one of the basic tools for defining and gradually implementing the common R and D policy. Progress has been achieved in energy research and specific items were selected out of the energy conservation objective.

III. THE SECOND ENERGY R & D PROGRAMME (ENERGY CONSERVATION)

III.1 General outline

The objective of the next R & D programme is to promote energy conservation in the Community by means of improved technologies, processes and industrial products, which have the potential of leading to commercial applications or demonstration projects.

It is envisaged to promote co-operation between organizations of at least two Member States and to encourage harmonization of related research activities in the Member States. The collaboration with the Rational Use of Energy (RUE) group will be continued and extended to demonstration projects after approval of the corresponding Council Regulation.

This programme includes :

a) the continuation of promising work started in the ongoing R & D programme,
b) new R & D work in such areas which show a high energy saving potential and
c) work proposed by the RUE group (e.g. information required for reglementations or norms for energy saving).
d) participation in IEA implementing agreements, if it is of benefit for the Community.

Since an inventory on energy R & D programmes of the Member States is not available at present and their future R & D programmes are often not yet known in details,the proposed second R & D programme does not contain the detailed description of specific projects. It should be considered as a frame programme, which allows the most promising actions to be selected according to the ACPM's criteria. Consequently, the subjects listed in the scope of the programme (Annex I) shall serve as a guide for the content of R & D proposals from Community organizations, firms and persons with a view to the provision of aid from Community funds. The framework programme will be specified and adapted at the beginning of its implementation according to the advices given by the ACPM. At that moment the results of the ongoing programmes on national and Community level will also be taken into account.

Energy conservation is mainly concerned with the end user. Consequently, the subdivision of the proposed second R and D programme reflects the three main energy consuming areas :

- domestic and commercial applications
- industry
- transport.

Moreover, the programme covers two other important areas :

- energy transformation and transport
- storage of secondary energy.

The objectives, the potential for energy savings and the scope of the proposed activities in these areas are given in Annex I.

The results of the proposed second energy R & D programme will be disseminated in status reports, final reports and in seminars in accordance with the Council Regulation (EEC) N° 2380/74 of 17.9.1974.

The need for energy conservation R & D activities is reflected by the existence of some large and strongly increasing national programmes.

The need for a continuation of the Community R & D programme is motivated as follows :

a) In assessing the research proposals and the results of the Community's energy conservation R & D programme a better liaison may be secured with and between the corresponding research work being carried out in the Member States. In this way unnecessary duplication of work may be avoided.

b) Several Member States of the Community are carrying out extensive energy conservation R & D programmes, which have little interaction. A Community energy R & D can serve as a platform, where

- information on ongoing work and results can be exchanged
- areas which are not adequately covered by national activities can be identified and
- co-operation between organizations of two or more Member States in projects of common interest can be initiated.

c) Many promising projects approved in the first energy R & D programme need further support in order to reach

- maturity for industrial application
- the marketing stage
- the demonstration stage, the implementation of which is foreseen in the frame of the proposed council Regulation on the granting of financial aids to demonstrate projects in the field of energy saving.

III.2 Funding

The first stage of the current energy conservation R and D programme was considered as a starting phase for the exploration of ways to implement this programme. In the second stage the more cost intensive laboratory experiments and tests with pilot plants were carried out on annual expenditures of 4 millions u.a., whereas in the first stage only 1.5 millions u.a. were spent. In defining the funds for the new 4-year programme for the period 1979-1983 the following items should be taken into consideration :

- the opinion of CREST that the Commission should concentrate strongest possible R and D efforts on energy conservation, the field which is recognized as a high importance ;

- the inflation in a four-year period ;

- the cost of a project increases considerably when it progresses from the research stage to the stage of components development and pilot plant testing. In the second R & D programme a larger number of second stage projects, emerging from the first programme, is expected. Consequently, the cost of the second programme will be considerably more expensive.

Keeping this in mind, average yearly commitments of 6,25 million E.u.a. are proposed for the energy conservation R and D programme in the four years.

Funding	1979	1980	1981	1982	1983	Total
millions E.u.a.	1,5	10	10	3	0,5	25

Since the staff available at present is not sufficient to run the ongoing programme in a satisfactory manner, additional staff will be required.

Moreover in order to advise the Commission in specific areas the assistance of additional outside consultants is proposed.

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IV. DETAILED DESCRIPTION

Introduction

In the following a description of the second four-year energy conservation R and D programme is given. It is proposed to subdivide this programme in five sectors :

- domestic and commercial applications
- industry
- transport
- energy transformation
- energy storage.

On the allocation of funds to the different sectors and on the determination of priority areas the advice of the ACPM will be requested.

The allocation of funds to the different sectors should be primarily determined by the energy saving potential which is influenced by the following factors :

Energy losses : Energy savings are expected to be possible by reducing losses in the different sectors. The size of these losses is to a certain extent a measure for the energy saving potential. These losses are estimated as follows : domestic and commercial 55 %, transport 85 %, industry 45 % and energy transformation 60-70 %.

Energy consumption : Also the size of the final energy consumption is a measure for the energy saving potential. For the sectors household , industry, transport and energy production the part in energy consumption was in 1975 approximately 39 %, 37 %, 16 and 8 % respectively.

Growth rate of energy consumption : This factor might give some insight in the development of future energy consumption. The growth rate is highest in the transport sector, medium in the domestic and commercial and lowest in the industrial sector.

Another important factor determining funding priorities for sectors and projects is the availability of fuels.

The relation of the availability of waste heat and heat demand is also an important element in establishing priorities, if in this way real fuel saving can be achieved.

Other criteria are : time required for commercialisation, probability of commercialisation, size of the market, payback time, cost-effectiveness of the R & D, reliability, and chance for demonstration and implementation.

Energy conservation should be introduced as a new constraint in the design of systems, processes and equipment, consequently, in the new programme the role of automation, and control for achieving energy savings in all sectors, should become an important factor ; this particularly in view of the rapid development of micro processors.

In the first programme, work has been predominantly done on hardware R and D. In the new programme, which is described in the following chapters, emphasis should remain on this type of R and D. The information on the result of the research and development should be disseminated extensively and adressed to manufacturers, architects, engineering groups, maintenance services and users.

The development of projects should also include a preliminary assessment of the energy saving potential in comparison with other state-of-the-art technologies, an evaluation of the expected size of the market, a preliminary economic analysis of the new product or process and an investigation of the potential barriers to commercialization (e.g. technical, institutional, social, environmental and economical barriers).

Sector A : domestic and commercial applications

Objectives

- develop more efficient heating and air conditioning systems and their components, in particular improved instrumentation and control.

- develop improved insulation materials and suitable processes for insulation of new and existing buildings.

- develop improved technologies for other domestic processes.

- develop heat pumps suitable for domestic application at a cost competitive with conventional systems.

- study houses and buildings as integrated systems including the study of the behaveour of their users.

Potential

About 44 % of the total final energy is consumed for domestic and commercial applications ; 39 % of the oil consumption is used in this area. In the year 1976 in the nine countries of the European Community the direct fuel usage was as follows :

- liquid petroleum products	185 Mtce
- natural gas	83 "
- solid fuel	34 "
- cokery gas	11 "
- In addition the primary fuel for electricity production was equivalent to	151 "

About 80 % of the energy used in this area is required for heating purposes. All the oil consumed in this area is burnt in heating systems, the efficiency of which still needs to be improved because the overall energy losses in this area are estimated at more than 55 %.

Energy conservation in this sector will be achieved mainly by the development of improved heating and air conditioning systems, including improved instrumentation and control systems, such as heat pumps using air, water or soil as heat source.

The type of heat pump and the heat source which can be used depend very much on the region of application. In the Atlantic region the system should be designed for heating purposes only (room heating and hot water production), whereas in the Mediterranean region a heat pump system is required, which serves for heating purposes in winter-time and for air conditioning in summer-time. The extraction of heat from the various heat sources raises environmental problems.

The overall efficiency of electrically driven heat pumps is strongly reduced by the weak conversion rate in electricity production due to thermodynamic constraints. The problem can be overcome by driving the heat pumps with a Diesel or gas engine, which allows to recover the waste heat of the engine, but ecological constraints should be considered.

The life time of mechanical components (compressor etc.) and the maintenance requirements should be such that heat pumps become competitive as compared to existing heating systems. The problem of life time and maintenance can be reduced by the development of advanced heat pumps, e.g. absorption heat pumps and hermetic systems.

Lastly, attention should be paid to such energy consuming equipment, such as electrical appliances and lighting.

District heating systems combined with heat-power coupling may have a high energy saving potential if the distance between the power station and the densely populated area does not exceed about 30 km, which seems to be a limit from the economical point of view.

An important reduction of energy consumption can also be achieved through improvements in design, insulation and ways of using materials for buildings. In spite of the fact that the percentage of new dwellings built per year is rather small (2-3 % per year), the accumulating effect over a ten years period will be substantial. Special techniques are required for the improvement of insulation in existing houses.

Scope of the proposed programme

Work in this area includes that carried out in sectors (a), (b) and (g) of the ongoing programme. It should be continued and extended.

Heating and air conditioning systems

- improve the efficiency of conventional heating, air conditioning and ventilation systems and their logic control systems
- recovery of waste heat
- improve the efficiency, reliability and lifetime of existing heat pumps systems, in particular of thermally driven heat pumps.

- develop advanced heat pumps (e.g. absorption heat pumps)
- develop mono and bivalent heat pumps applications in new and existing houses and buildings (e.g. improved logic control system, large surface low temperature radiators)
- investigate the environmental and energy consumption impact of large scale introduction of heat pump systems.

Domestic equipment

- improvement of efficiency (lighting, electric appliances, etc...)
- recovery of waste heat from domestic equipment.

Structure and insulation of buildings

- development of heat leak detection technology and its application
- develop improved application techniques for insulation materials in new and existing buildings
- develop better designs for buildings and improved ways of using materials.

Heat storage

- develop heat storage systems and their control equipment
- develop the application in domestic heating and hot water production.

Sector B : industry

Objectives

- develop new and improved technologies for various energy intensive industries aiming at a reduced specific energy requirement . The application of the developed new conservation technologies should not be restricted to one specific case
- utilize residual heat as alternative fuel
- develop energy management techniques.

Potential

About 39% of the total final energy is consumed in industry ; 25 % of the oil consumption is used in this area. In the year 1976 in the nine countries of the European Community, direct fuel usage in industry was as follows :

- liquid petroleum products	120 Mtce
- natural gas	67 "
- solid fuel	56 "
- cokery gas	24 "
- The primary energy required for the electricity production was equivalent to	150 "

About two thirds of the overall energy is used for industrial heating purposes. The energy losses in the industry are about 45 %.

In spite of the intensive rationalization efforts undertaken in the last 10-15 years, there is still an important saving potential for residual heat utilization.

Presently industry is faced with both the energy saving problem and the more stringent environmental constraints. In order to solve these problems R and D work and the implementation of demonstration plants are required. However the production plants cannot be readily reconstructed. All these measures are however hampered by the fact that these industries are capital intensive and production oriented. Consequently, due to the market forces, R and D work will preferentially be directed at new product development, whereas energy saving will only be considered if the price of the fuel increases exceedingly or if there is a governmental stimulation for actions.

Energy savings up to 20 % may be reached in many processes ; however, implementation of energy saving techniques requires a rather long delay due to the lack of capital for large new investments and loss of returns during tranformation. For the same reasons the implementation of new production techniques and the substitution of products and materials by others consuming less energy will have a low priority in the industry. In spite of these facts it is important to develop energy conservation techniques and to demonstrate their feasibility in order to have them available, whenever plant modifications have to be carried out for other reasons. Moreover energy management in all systems can lead to substanstial energy savings.

Special attention should be directed to the reduction of residual heat losses in energy intensive industries. The chances for residual heat recovery depend on the operating temperatures of industrial processes, which are ranging between 100 and 500 °C in the chemical industry, 600 and 900 °C in the non ferrous metal industry and above 1000 °C in the ceramics, glass and iron and steel industries. Therefore special attention should be paid to the relevant equipment and processes (e.g. combustion and high temperature insulation).

Consequently, the principal option for energy savings in industry is to utilize residual heat as alternative fuel. The possibilities for energy savings should be investigated and technologies should be developed for the various energy intensive industrial production processes, notably :

- petroleum refineries
- chemical industries
- primary metals
- glass, ceramics and cement
- pulp and paper
- textile
- food processing

in which an important part of the energy consumed by the industry is used.

Since the industrial production processes in the Member States are similar, it is expected that the R and D work may be combined for greater efficiency and for a more economic use of funds.

Scope of the proposed programme

Work in this area includes that carried out in sectors (d) and (g) of the first programme and should be continued and extended.

Development of energy saving technologies

- Continuation of research on the recovery of heat (liquid, and gaseous effluents). Further development of existing and advanced energy saving technologies and improvement of the efficiency in the energy intensive branches of industry, such as non ferrous metals, iron and steel, chemical, oil-refineries, textile, glass, ceramic, food and paper and pulp industries.

- In order to assess the possibilities for energy management and savings in various industrial sectors in a more systematic way, energy analyses for the most important branches of industry should be made in order to give information on the type and quantity of the fuel used and to establish priorities for the R & D programme.The fluctuation of the energy demand and the amount, temperature, type of waste heat discharged and the possibilities for application of available energy storage systems should be studied.

- Optimize the combination of components in an installation, and avoid overdimensioning of components in systems (e.g. electric motors).

- Energy saving by recycling of materials, if the prevailing aspect is energy conservation.

Development of energy saving components and processes

Several components used for energy savings are not specific for one particular industry. These components can have a fairly large market and research is therefore important, notably :

- Heat exchangers : Improvements are still possible with gas-gas and heat-pipe exchangers. Much work on high temperature heat exchangers 700-1000 °C still has to be done. Moreover, the development of compact cheap heat exchangers with a high efficiency is indispensable for a large scale introduction in industry of low grade heat recovery or conversion systems.

- Organic Rankine Cycle engine for power production from low grade waste heat (about 300°C) should be further developed, if there is more potential for mechanical power application than for direct heat utilization.

- Development of high temperature heat pumps and their components (e.g. heat exchangers), for industries requiring heat at 70-150 °C such as the food industry.

- Ways to improve the efficiencies of industrial boilers (combustion and heat transfer) and furnaces (high temperature isolation).

Sector C : transport

Objectives

- improve the efficiency of existing engines taking into account environmental constraints

- develop improved traffic systems.

Potential

About 17 % of the total final energy is consumed in the transport area ; 36 % of the overall petroleum consumption is used in this area. Oil is the main fuel used in this sector. The losses are about 83 % mainly due to physical reasons. Further energy saving is required. Diesel engines seem to be more economical than Otto-engines, in particular in urban transport when the vehicles are operating at part load conditions. On high ways this difference in fuel consumption is less significant. Improvements of the combustion efficiency of engines are possible in various ways : by improved tuning, stratified charge, lean burning, and in a longer time range the Stirling engine. An important fuel saving may be achieved by streamlining the shape of motor lorries and use of fly wheels in large vehicles (busses, underground etc.).

It should be emphazised that energy saving is hampered by environmental constraints. This requires investigation of various scenarios.

The electrical vehicle must be considered as a major long term option, which is closely linked to the electric utility

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sector and depends on the development of advanced batteries. The availability of service systems would increase wider utilization.

Scope of the proposed programme

Engines, vehicles and transport systems with improved energy saving technologies should be developed in as much as the energy saving aspect is prevailing and if the work would not be performed without public incentives.

Improvement of internal combustion engines

- Continuation of work on improved types of engines, also under part-load conditions.

- Further development of advanced Diesel and Otto-engines taking into account environmental constraints.

- Alternative concepts for car traction.

Electrical and hybrid vehicles

- Development of electrical vehicles and high energy density batteries for car traction (the last subject will be discussed in the chapter on energy storage).
- Hydrogen concept for car traction
- Use of methanol & athanol as alternative fuel.
- R & D on hybrid concepts for car traction, including recovery of brake energy.

General studies on transport systems

Urban conditions should be considered.

Improvement of vehicle structure

Stream-lining, lower friction, lighter weight, automatic gear box and other components.

Sector D : energy transformation and transport

Objective

- save energy in different energy transformation processes (e.g.recovery of waste heat, development of more efficient installations)

- develop technologies which promote the use of coal and low grade fuels instead of oil, in so far as this aspect is not covered by the ECSC Treaty.

Potential

In view of the fact that the world coal resources are an order of magnitude larger than oil and gas resources, technologies which promote the use of coal should be developed. Fluidized bed combustion or gasification are such technologies. Their main advantages are : high heat transfer, low SO_2 levels in fumes when limestone is added, prospect of firing gas turbines with coal, reduced fouling and corrosion of heat transfer tubes, low grade material can be fired, reduced dimensions as compared to a conventional coal fired boiler.

In a strategy where the use of coal will increase strongly, R and D on Diesel engines which use low grade gas should be stimulated. Coal gasification producing low grade gas is presently the most promising coal gasification process.

The present LNG consumption in the Community is $6.3.10^9$ TJ. The use of LNG is strongly increasing. The primary energy required for the liquefaction of one m^3 of gaseous LNG is 6300 MJ. Recovery of a part of this energy during LNG evaporation in the gas terminal,is found to have an important energy saving potential, by means of a gas turbine operating in a closed cycle at temperatures between - 160 °C and 700 °C.

The production of electricity offers two directions for energy saving :

- By producing electricity in combination with heat for district heating of buildings, the overall seasonal conversion efficiency can be raised to 55 %. The impact of heat-power coupling might be very important in the long term. The EUR 5929 report* for CREST stressed the importance of large scale low temperature heat storage for improving the seasonally averaged overall efficiency of heat-power-district heating systems.

- In order to use waste energy and to maximize the efficiency of the overall energy utilization from the source to the ultimate end use, energy cascading techniques should be studied and developed further.

Scope of the proposed programme

A part of the work proposed on energy transformation is already going on in different parts of the current programme, e.g. recovery of energy from LNG evaporation (subsector d), low BTU gas engines (subsector g), energy from waste and fluidized bed combustion (subsector f).

Energy from waste and fluidized bed combustion

The co-ordinated programme on fluidized bed combustion for urban waste and low grade coal waste should be extended to fluidized combustion for all solid fuel. Both large installations for industry and smaller ones for domestic applications should be studied.

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* R & D in respect of energy storage, - evaluation of programmes in progress within the Community.

The activities should be coordinated with national and international programmes in order to avoid overlapping and duplication.

LNG - gasification

The recovery of a part of the LNG liquefaction energy in a closed cycle gas turbine, thus improving the thermodynamic efficiency for electricity production, should be further explored.

Heat-power production

The seasonal efficiency of combined heat-power production which at present is about 55 %, due to the fact that in the summer no heat is required for domestic heating, could be improved with seasonal low temperature (50-100 °C) heat storage. R and D on large scale heat storage in an aquifer should therefore be continued and co-ordinated with activities going on in the geothermal programme.

Advanced engines for electricity production

R and D on large Diesel engines up to 40 MW combined with waste heat utilisation aiming at a higher efficiency should be performed. The use of a larger variety of fuels (e.g. coal, low BTU gas) should be further explored.

Energy cascading devices

The application of topping and bottoming devices for industrial processes (e.g. recovery of flue gas heat) should be further explored.

Sector E : energy storage

Objectives

- develop cost effective low temperature (50-100 °C) seasonal heat storage, medium temperature (300-500 °C) daily and weekly heat storage.

- develop short and long term storage of electricity

- develop short term mechanical energy storage in fly wheels for industrial and transport purposes.

Potential

Storage of secondary energy has an application in all energy consuming sectors. The impact will be strongest in domestic heating and transport. In the report of EUR 5929 on storage of secondary energy prepared for CREST,R and D on the topics mentioned below was recommended.

The totalamount of waste heat discharged from power plants in the Common Market amounts to about 20 % of the primary energy consumption.

Large scale seasonal low grade heat storage (hot-water lakes, aquifers) would enable to use heat from power plants which would have been discharged otherwise.

Large scale storage of medium temperature heat for steam production of power plants (300 °-500 °C) would enable the use of this heat in peak hours. This load leveling has the advantage that electricity for peak hours need not to be produced with gas turbines, which have a low conversion efficiency. Medium temperature heat storage would be particularly useful in a situation where fossil fuel becomes scarce and where electricity is predominantly produced with nuclear power plants, which cannot be easily switched off and on.

Storage of electricity has an impact on the transport and power production sector.

If a large part of the car traction could be electrified with help of high energy density batteries, considerable oil savings and pollution abatement could be achieved, in particular :

- Mechanical energy, produced by large power plants and stored via electricity in high density car batteries, could be produced with 25 to 30 % efficiency (allowing for 20 % losses in the battery and in the car engine) instead of the present 15 % efficiency of petrol engines.

- If the electricity is produced in heat-power coupling, a part of waste heat can be used for domestic heating. Electrification of car traction thus offers the opportunity to recuperate a part of the waste heat (in the power station), which is presently lost in cars.

- If a large part of the cars is driven by batteries and these batteries are loaded during the night, they form an important load leveling device and thus contribute to extra energy savings.

Storage of electricity for load levelling has the same advantages as the ones mentioned previously under medium temperature heat storage for power plants. An additional advantage is that electricity can be stored locally near the consumers which avoids over loading of the distribution system.

Storage of electricity is also essential for alternative electricity production (solar, wind, waves).

The report EUR 5929 stressed the importance of a close co-ordination of advanced battery R and D in Europe. This has in fact started already in the present programme.

Batteries are too expensive for storage times longer than a few days. Fuel cells might be an interesting tool for long term storage if the investment cost of the combination : electrolyser-hydrogen storage-fuel cell will be sufficiently low. This will be extremely difficult but as, a part from hydrostorage, no other means for long term electricity storage are available, this might be a solution which should be assessed.

The impact of fly-wheels on energy savings is still difficult to evaluate, as little R and D has been done. By connecting a generator , which can also be used as an electrical motor, on the axis of a fly-wheel rotating in vacuum, energy can be stored or extracted. Fly-wheels are at an early stage of development and have still a long way to go. The storage capacity can be enhanced by using glassfibers and composite materials which are stronger and allow a higher rotation speed. A fly-wheel has a high power density and might be used for electrical car traction in combination with batteries. It might be also possible to use fly-wheels for load-leveling and in industry.

Scope of the proposed programme

Energy storage has been added as a special section but it should be kept in mind that the type of storage is always closely connected with different energy consuming applications, which should be investigated as a complete system.

Heat storage

- R and D on low grade heat storage for individual houses and buildings (e.g. heat pumps, solar energy) using sensible heat of soil and sensible, latent or chemical heat of different chemical compounds. Different low cost techniques should be developed such as hybrid storage systems using gravel and water for storing energy where the fluid has the additional task of transporting the heat to where it is required.

- R and D on large scale low grade heat storage such as aquifers and hot-water lakes to be used in combination with district heating.
- R and D on low grade seasonal heat storage.
- R and D on heat storage for industrial purposes and for peak leveling.

Electrochemical storage

Development of advanced batteries with a high energy density (Na/S, Li/S, all solid state batteries, batteries with organic electrolytes) for applications such as car traction, load leveling and alternative energies (sun, waves, wind). This R and D work should be done on three levels :

- Materials R and D on electrolytes and electrodes in order to systematically search for interesting combinations. In such a search the requirements for a particular application (car traction, solar, wave etc.) should be taken into account.

- More applied R and D which should deal with the practical problems when a particular battery is further developed (seals, corrosion etc.). The work on Na/S and Li/S batteries falls in this category.

- Pilot systems, where advanced batteries are tested in complete systems (cars, solar power plants etc.).

The first two levels of R and D are presently done in the ongoing R and D programme and should be continued and extended with assessment studies to formulate goals.

R and D on fuel cells has been done for a long time and commercial applications are not yet in sight. One reason for this rather disappointing result might be the fact that fuel cells R and D too quickly embarked on large scale engineering. A rather fundamental R and D programme directed towards R and D on materials for fuel cells, of the same type as the work which has recently started on advanced batteries, in the framework of the Commission's Energy R and D Programme, might be a good approach. The problems in fuel cell and battery R and D are strongly related, and a coherent fuel cell and battery materials R and D programme might be possible. The development of a cheap catalist should have a first priority.

This type of R and D could be mainly done by universities in close collaboration with industries, which could use the results for applied development and industrial realization.

Storage of mechanical energy

R and D on fly-wheels for hybrid traction of heavy vehicles (trams, busses etc.) should be continued.

R and D on fly-wheel application in industry for peak power leveling should be further explored.

SURVEY OF THE FIRST ENERGY R & D PROGRAMME
(ENERGY CONSERVATION)

The programme is subdivided in 8 sectors :

Sector a : Improvements of insulation in buildings (10 contracts committed)

Research during the first four year programme has started in three main directions :

- The improvement of insulation materials such as wall insulation and selective surfaces for windows.

- Assessment of ways in which low cost housing can be designed and constructed (walls, floors, roofs, windows, air tightness, orientation, thermal capacity) cost effectively in such a way that energy consumption is as low as possible. This work is done in a co-ordinated programme executed by laboratories from the United Kingdom, Netherlands and Belgium.

- Development of infra-red detection techniques to be able to quickly identify heat leaks in houses.

Sector b : Heat pumps (24 contracts)

The R and D programme on heat pumps resulting from the call for tenders was shaped as follows :

- Component research on heat exchangers for air heat pumps (frosting, defrosting) and heat pump fluids.

- Heat sources and seasonal heat storage in soil for heat pumps.
  In a co-ordinated study Belgian, Danish, Dutch and German laboratories are assessing the possibilities and draw backs (environmental impact) of soil, water and air as a heat source for heat pumps.

- Advanced heat pumps
  A large range of advanced heat pumps is developed such as absorption heat pumps, organic Rankine cycle engine driven heat pumps, gas engine driven heat pumps, large 10 MW diesel driven heat pumps and high temperature heat pumps for industrial purposes.

- Heat pumps integrated in systems
  The behaviour of heat pumps integrated in systems such as single rooms, single houses, apartment buildings and district heating systems is studied. Development of control systems forms an important part of these studies.

Sector c : Urban transport (6 contracts)

In this programme the improvement of diesel engines (e.g. non coolant diesel engine) and ways to develop an engine which combines the advantages of the Diesel and Otto-engine are studied. A general assessment minimizing the overall energy consumption in the petrol refining industry and car-traction is done, taking into account environmental constraints. This R and D work is executed by ten large European car firms in collaboration with the oil industry.

Sector d : Recovery of heat (21 contracts)

In this sector the recovery of heat in industry forms the major part. Research has developed along two different lines :

- The development of a technology to recover heat for a particular branch of industry such as coke, aluminium, textile and glass industry, food, paper and pulp and the desalination plants. Also the recovery of energy used for the liquification of LNG belongs to this category. Work in the pulp and paper sector is co-ordinated (UK, F, NL and D).

- The development of components which serve for the recovery of heat such as heat exchangers, organic Rankine cycle engines. A large part of the R and D in heat exchangers is devoted to the application of heat pipes.

Sector e : Recycling of materials (2 contracts)

Not many proposals were received in this sector and only 2 contracts have been signed (recycling of waste plastic).

Sector f : Energy from waste (5 contracts)

Research is mainly directed towards the development of fluidized bed combustion or gazification for burning materials with a low energy value. This work is executed in a co-ordinated programme by two French industries and the U.K. National Coal Board.

Sector g : Assessment of specific energy consumption (26 contracts)

This field is very diverse and energy conservation studies are being executed for different branches of industry. These studies can be divided in two types : development of an energy conservation technology and an energy analysis of the industry. Often the two are combined.

A study covering both fields is carried out on the paper industry. This work is executed in a co-ordinated programme with institutes and industries from different countries.

Several studies on improving the combustion and boiler efficiency of industrial boilers are going on. The oxygen combustion technology is assessed and some specific energy saving methods are developed for blast furnaces.

Energy analysis studies are going on on domestic heating and hotwater production systems and the food, textile, chemical and mechanical industry. A general cost-benefit analysis for energy savings in the chemical industry is executed.

Sector h : Storage of secundary energy (10 contracts)

This field can be divided in heat storage, electricity storage and mechanical storage.

Several studies cover the field of low temperature storage (50°-150°C) with inorganic and organic compounds. Material properties such as cycling, life time are investigated for a series of inorganic compounds which can serve as a storage medium in the temperature range of 200° to 600°C.

In the field of power storage, R and D is mainly done on advanced batteries. High energy density batteries such as Li/S and Na/S batteries are developed and a co-ordinated programme on materials R and D for electrochemical energy storage devices is executed by seven institutes and universities in the U.K. and Denmark.

A preliminary study on fly-wheel storage up to 2 MW and its application in industries is executed.

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The technical programme of some R & D contracts is described in the status report 1977 on the Community energy R & D programme (EUR 5889). An updated status report will be published in 1978.

PRODUCTION AND UTILIZATION OF HYDROGEN

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Contents

I. INTRODUCTION

As the overall energy demand of the world will increase in the future and the total availability of fossil fuels is limited we shall sooner or later have to reduce their use for producing energy, as they constitute a precious feedstocks for chemical industry.

It can also be expected that the price of energy will steadily increase, thus stimulating the introduction of alternative energy sources.

Energy can be obtained from several new sources: particularly nuclear fission reactors (and later nuclear fusion reactors), large scale solar and geothermal power plants, etc.

The energy produced has to be conveyed efficiently to the user, the nature of the utilization and the transport distance influencing the overall efficiency of the process.

The main large scale energy vectors are: electricity, synthetic hydrocarbons (either liquid or gazeous) and hydrogen.

Hydrogen as an energy vector offers many advantages: it is easily produced, stored and transported and it causes no postcombustion pollution. It can be produced from water either by electrolysis or - at least in principle - by thermochemical splitting, stored and distributed in liquid or gaseous form or in a metal compound, reconverted into electricity in a fuel cell, burned to produce heat or mechanical energy in a conventional internal combustion engine (urban transport).
It can also be used as a raw material in the chemical, petrochemical and metallurgical industries. In transport, use can be done of the already existing natural gas network.
The role of hydrogen in the future energy market could supplement that of electricity and in particular be valuable for large scale storage of energy. Its production by electrolysis could also be useful as a load regulating means to stabilize the consumption of electrical energy during the off peaks periods.

Even if the price increase of fossil fuels will not support an early widespread use of hydrogen as energy vector the use of electrolytic hydrogen for ammonia synthesis is likely to create already in the next years (*) a new large scale hydrogen production technology on the market.

In the long run however, hydrogen is likely to play a very important role as one of the major energy vectors.

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*) although ammonia is not an energy vector it should be borne in mind that its synthesis using hydrogen from electrolysis, produced by nuclear electricity, would mean a considerable saving of fossile energy sources.

To summarize:

- Hydrogen is a very important raw-material already used in very large quantities for the chemical industry, its use can be easily extended to other industrial applications. Such an extended use would lead to a net saving in primary energy.

- Hydrogen as an energy-carrier will constitute an essential factor in the long-term energy system, mainly when fossile fuel supply becomes insufficient, and new energy sources will be exploited.

- Hydrogen is easily stored and transported in large quantities allowing large energy storages.

- The present and, particularly, the potential markets are large enough to justify a research effort in this field, to improve the production methods with the aim of a higher overall efficiency leading to lower energy consumption and better use of existing resources.

II. OUTLINES AND STATE OF PROGRESS OF THE FIRST PROGRAMME

The main aim of the first indirect action R&D programme on the production and utilization of hydrogen (1 July 1975 - 30 June 1979) was to accelerate the verification of the technical and economic feasibility of producing and using hydrogen as an alternative energy vector in a future energy market.

The programme was subdivided into three main subjects:

- Project A :

  Thermochemical production of hydrogen, dealing with the study and development of thermochemical cycles for decomposing water.

  This project was specifically connected with the work carried out in the Joint Research Center of Ispra.
  Considerable progress in the development of thermochemical cycles has been accomplished by the joint direct and indirect actions.
  Two "hybrid" cycles (including an electrolytic step) are now in an advanced status of experimentation. The design of a small prototype installation for these cycles is anticipated to be well advanced at the end of the present programme.

- Project B :

  Electrolytic production of hydrogen, dealing with the improvement of existing technology and the development of advanced electrolysis methods.

  The project work carried out during the first programme has led to some very promising achievements. Improvements of the electrolytic production process have been obtained following different lines of approach.

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These results are actually going to be confirmed either in small scale (5 - 10 KW) or in medium scale (up to 100 KW) electrolyzers. The laboratory results show that power consumption for water electrolysis has been lowered from an initial 5 KWh/Nm^3 H_2 to 3.6 KWh/Nm^3 H_2 at 5 - 10 kA/m^2.

The corresponding hydrogen cost will be around 8c UCE/Nm^3 for an energy cost of 1,6 c UCE/KWh. This cost is not too far from the cost of hydrogen from methane reforming.

- Project C:

Utilization of hydrogen, dealing with the specific problems of hydrogen transportation, storage, utilization and safety allowed to produce and collect a considerable amount of data on safety, on potential transportation problems, on possible utilizations beyond the well known uses in chemistry and petrochemistry, on storage methods, on structural materials and their best treatment for optimum mechanical behaviour when exposed to hydrogen.

Taking into account that hydrogen as an energy vector is only of interest in the long run, the first programme can be considered as successful.
The rate of expenditure and its breakdown, however, differed substantially from the figures foreseen at the beginning of the programme.
Generally speaking it can be said that the majority of research proposals received were dealing with fields relatively near to commercial application,for which the contractor is more ready to invest on own financial contribution. This could explain why only few proposals were presented for project A and why the financial contribution requested from the Commission by the contractors of this project was mostly higher than 50 %.

In order to avoid this shortage of proposals a change in the funding policy would be needed for proposals in project A.
In this field the objectives are very long term, or the risk is very high.
Such a change in funding policy could be justified also by the fact that it would better enable the indirect action to supplement the work of the JRC by specific studies on request, to be carried out by third parties.

In special cases where industrial interest is relatively small funding up to 80% of the total expenditure could help, in the three project, to maintain the size of the programme and a reasonable timing.

The potential long term market for hydrogen is enormous, although there might be a difference in time-scale and interest between countries having the possible alternative of using coal to supplement their energy input and countries where an early development of nuclear power stations is foreseen, so that cheaper off-peak electrical energy will be available early. This latter situation will enhance the introduction of non fossil hydrogen into the market long before dedicated nuclear plants for producing hydrogen can be competitive.

The Community has a technical lead in the field of the thermochemical hydrogen production and in the field of alkaline electrolysis, although

their relative state of development is quite different.
The state of the art in high temperature solid electrolyte electrolysis is at least encouraging and further studies are well warranted.

It is worth pointing out that considerable time is needed to introduce new technologies and consequently that a subsequent pluriannual programme of R&D will be needed to exploit the results of the first programme.

Prototype construction and operation are the next steps needed to insure further developments. The corresponding results may bring us nearer to the large scale use of electrolytic hydrogen as a chemical feedstock and later, to a general use of hydrogen as an energy vector.

To evaluate the mutual interference of alternative fuels with hydrogen and to estimate more accurately the break-even points of the different options, a specific subtask should be foreseen within the project C.

It should also be stated that several cross relationships between the hydrogen programme and other programmes have become evident. Two concrete examples are shown below:

- conceptual studies for hydrogen production from solar energy could be investigated (link with solar programme).

- The whole issue of energy storage is strongly depending on the success or failure of storing hydrogen as a secondary energy vector (link with energy conservation programme or a separate storage programme).

These new lines of R&D require some consideration. Their introduction in one of the concerned programmes is suggested.

III. THE SECOND RESEARCH AND DEVELOPMENT PROGRAMME

This programme should again be divided into three main subjects, each of which would be assigned to a project leader assisting the Commission for its detailed technical and scientific management; the coordination of the three projects, together with the centralized general management, would again be the responsibility of the programme coordinator. The three projects concern thermochemical production, electrolytic production, transportation, storage and utilization of hydrogen.
These subjects or projects are outlined below:

III.1. Project A - Thermochemical hydrogen production

Thermochemical production of hydrogen is the more recent approach in which the decomposition of water is obtained by direct use of (nuclear) heat.

During the first programme the understanding of this venture advanced considerably in spite of the intrinsic difficulties of such a pioneering work.

Of the many cycles proposed and studied during the last years three have been selected for further experimentation and development as being those which have the highest probability of success. Two of them require an electrolytic step (hybrid cycles), one is purely thermochemical.
Since the feasibility of the various steps of the thermochemical cycles has been demonstrated on a laboratory scale, bench-scale closed-loop experiments are now in progress. Their achievement at the JRC is expected before the end of the first indirect programme.
Due to the fact that no previous experience is available, the outcome of these experiments is decisive for the construction and continuous operation of a prototype of the size needed to evaluate the technico-economic feasibility of thermochemical cycles.

In the second indirect programme it is proposed to continue to assist the JRC on the collection of experimental data on the cycles selected for develoment. The design and operation of small-scale closed cycle experiments is equally proposed. Only cycles giving positive results at the end of the first programme should be considered.

A limited effort of search for new, more efficient thermochemical cycles will be maintained.

In order to continue this project, the Commission proposes to maintain the close interconnection between the indirect action and the work of the Joint Research Centre, so as to make the maximum use of the overall results.
The work done on this project by indirect action should expand and supplement the corresponding work done by direct action at the JRC.

In order to carry out this project a budget of 1 MUCE is proposed for the period July 1979 - June 1983.

III.2. Project B - Electrolytic production of hydrogen

Although the production of hydrogen by electrolysis of water is a well known and relatively old technique, no large research effort was made until recently due to its minor commercial importance.
The interest in this technique has been recently renewed by the fact that cheaper off-peak electrical energy might become available relatively soon. In these conditions, improved electrolytic cells could produce hydrogen as a chemical feedstock at prices competitive with hydrogen produced by other methods.

Four lines of development were successfully followed during the execution of the first programme :

- low temperature alkaline electrolysis (80 - 120°C) using electrodes containing newly developed, highly active electrocatalysts;

- medium temperature alkaline electrolysis and new separator materials (150 - 200°C) using activated metal electrodes or catalysts;

- low temperature (80 - 120°C) alkaline electrolysis using a new inorganic solid electrolyte and active electrocatalysts on the electrodes;

- high temperature solid-state electrolysis (800 - 1000°C) of water vapour.

The results obtained from these approaches - low/medium temperature alkaline electrolysis - are very encouraging and comparable in spite of the different ways followed.

Operation of small laboratory prototypes (5 - 10 KW) should demonstrate, before the end of the first programme, an energy consumption of about 3.6 KWh/Nm^3 of hydrogen produced.This improvement results in a substantial reduction of energy consumption when compared to the energy consumption of existing commercial electrolyzers.

In the new programme it is proposed to extend the studies of new electrode materials, and of new diaphragm or membrane materials.

Study and evaluation of non conventional technologies, like the use of solid polymer electrolytes and high temperature electrolysis are equally proposed.

The evaluation of the approaches developed during the first programme should be completed. For this the construction test and operation of cell-modules of about 100 kW is proposed. The modules should allow easy extrapolation of the operating data to full size units.

The advice of the ACPM will be particularly sought when determining the size of the cell modules on the basis of the progress of the programme.

In order to carry out this project a budget of 12 MUCE is proposed for the period July 1979 - June 1983. Participation of industrial large-scale H_2 producers and users in this programm is to be encouraged.

III.3. Project C - Transportation, storage and utilization

The broad range of this project had been foreseen to cover the multiplicity of problems which may be possibly encountered with large scale hydrogen utilization.

In spite of the diversity of the matter, a well coordinated grouping of subjects has been investigated during the first programme, covering its most important points.

Data on safety of hydrogen use, on handling and on existing safety regulations have been collected extensively.

The possibility of using existing natural gas distribution networks for hydrogen transport has been investigated.

Small to medium-scale storage on hydrides in cryoadsorbers as well as hydrogen use and distribution for automotive traction were studied.

The sensitivity of steels to hydrogen, corresponding measurement methods, as well as the influence of several important parameters were investigated.

Extension and conclusion of several studies are needed as well as research and development of subtasks not yet dealed with, but which are indispensable for a safe and widespread use of hydrogen in the future.

These studies will cover mostly the compilation of safety manuals, the analysis of storage methods and of related problems, the uses of hydrogen.

In order to carry out this project a budget of 2 MUCE is proposed for the period July 1979 - June 1983.

III.4. Summary and breakdown of the proposed funding (in muce)

Project	Total	1979	1980	1981	1982	1983
A. Thermochemical production of hydrogen	1,0	0,07	0,4	0,33	0,13	0,07
B. Electrolytic production of hydrogen	12,0	0,8	4,8	4,0	1,6	0,8
C. Transportation storage and Utilization	2,0	0,13	0,8	0,67	0,27	0,13
Total	15,0	1,0	6,0	5,0	2,0	1,0

IV. DETAILED DESCRIPTION

IV.1. Project A - Thermochemical Production of hydrogen

Objectives

- Operation of a few laboratory closed cycle experiments for a more accurate technico-economic evaluation of the processes. (JRC)

- Evaluation of the technico-economic data of the optimized processes and cost assessment.

- Advanced studies: evaluation of new cycles.

The indirect action collection and evaluation of data shall be complementary to the development of thermochemical processes at the JRC.

Description

- Thermochemical cycle development

Complementary contributions to the JRC actions in the following fields:

- Further evaluation of new cycles leading to potential improvements over existing cycles. Few steps, high efficiency and easy implementation will be sought. (limited effort).

- Exploitation of bench scale experiments for technological data collection (hydrogen production roughly 100 l/hr).

- Specific open or closed loop experiments for heat exchange and corrosion measurements.

- Data collection, economic assessment and perspective evaluations.

Experimental work should only be undertaken on cycles giving positive results at the end of the first programme.

Funding

For indirect action on Project A, a budget of 1 MUCE is proposed for the period July 1979 - June 1983.

TOTAL MUCE	1979	1980	1981	1982	1983
1,0	0,07	0,4	0,33	0,13	0,07

IV.2. Project B - Electrolytic hydrogen production

Objectives

a) Extend and complete the know-how for prototype design and fabrication, the target being electrolyzer modules of 40.000 to 100.000 Nm^3/h.

b) Further laboratory development of electrodes, diaphragms and membranes and of advanced electrolysis concepts.

c) Construction and operation of prototypes of advanced electrolyzers.

d) Development of multiple cells and laboratory prototypes for high temperature electrolysis.

Description

- Improvement of conventional electrolytic processes
  - Further development of improved electrocatalysts (yielding low overvoltages).
  - Evaluation of acid electrolysis using novel materials and techniques (e.g. plastics, electrodes based on oxides).
  - Improvement of membranes and diaphragms, further development and study of organic and inorganic solid polymer electrolytes (acidic or basic).
  - Evaluation of specific cell design aiming at low cost and low maintenace.
  - Development of improved high efficiency gas separators.

- Development of advanced electrolytic cells
  - Design, construction and operation of several electrolyzer modules of about 100 kW each, based on the most advanced results of alkaline electrolysis. The size of these modules should be easily extrapolable to full size electrolyzers and shall allow a correct estimation of all pertinent parameters. The size of the modules will be decided on the basis of the progress and degree of succes of the specific concept to be tested, taking also the advice of the ACPM.
    A parallel laboratory programme for specific studies and for complementary developments would be needed for each prototype.
  - Data collection, elaboration, economic assessment and perspective evaluation for each prototype.
  - Studies of system engineering for optimization of all design parameters to minimize the cost of the overall system.

- High temperature electrolysis

  - Improvement of the actual technology of cells and of constitutive materials.

  - Development of laboratory prototypes. Study of scaling up strategies and alternatives.

  - Design, construction and operation of a small (10 - 100 KW) laboratory prototype. Cost analysis and evaluation of the development perspectives.

Funding

For the indirect action on project B, a budget of 12 MUCE is proposed for the period July 1979 - June 1983.

Total MUCE	1979	1980	1981	1982	1983
12	0,8	4,8	4,0	1,6	0,8

IV.3. Project C - Transportation, Storage and Utilization

Objectives

a) General comparative analysis of the possible uses of hydrogen in comparision and as replacement of other energy vectors.

b) Compilation of a safety manual and identification of first elements which could govern safety regulations for hydrogen.

c) Further analysis of storage and transportation methods. Study of new technologies for storage, evaluation of large scale storage and of the corresponding problems.

Description

- General studies

  - Evaluation of hydrogen as an alternative energy vector and of its specific role as a complement for electrical energy.

  - Preliminary conceptual design of distribution networks.

- Safety aspects

  - Preparation of a general safety manual and of preliminary elements for regulation proposals.

  - Collection of data on combustion and explosion.

- Transport and storage

  - Evaluation of large scale hydrogen storage and of the corresponding problems. Evaluation of the auxiliary equipments needed. Economic assessment of such storage.

  - Evaluation of other hydrogen storage methods.
    Conceptual evaluation of possible methods of producing electrical energy from hydrogen.

  - Listing of suitable materials and components for hydrogen use and transportation.

Funding

For the indirect action on project C a budget of 2 MUCE is proposed for the period July 1979 - June 1983.

Total MUCE	1979	1980	1981	1982	1983
2	0,13	0,8	0,67	0,27	0,13

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SOLAR ENERGY

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Contents

I. INTRODUCTION

The prime purpose of the proposed programme is to develop solar energy to such a stage that it may contribute to meet the energy needs of the EC. Hence, this programme must necessarily be part of a long-term energy strategy because in the energy sector, leadtimes for the introduction of a new technology are counted in decades: As the effort on solar energy, even at a modest scale, is only very recent, a greater contribution of solar energy to the EC's energy scenario can be anticipated only beyond the year 2000. It is important to note, however, that progress achieved since the recent oil crises is quite spectacular: In the EC, thousands of domestic water heaters and solar heated swimming pools were built and thousands of straw burners were sold. This had also a small but meaningful impact in the employment sector: approximately 200 companies in the EC rushed into the solar heating market. Even in the photovoltaic sector where the gap of development work in the fifties and sixties needs time to fill up, the recent involvement of some important companies from the electricity industry and the oil industry speaks for itself. These first achievements are encouraging signs for the future.

At our present state of knowledge no definite technical barriers could yet be identified to the future large-scale utilisation of solar energy in the EC which could not eventually be overcome by an appropriate R & D effort. It is obvious that the exact contribution of solar energy is a matter for speculation because it depends largely on the evolution of fossil fuel prices in the coming years, success in reducing capital cost of solar equipment, and on the awareness and political strength to increase the energy independence of the EC, i.e. in other terms, how large an effort will be made on unconventional energy sources. It is reasonable to expect a solar contribution in Europe up to 5 % by 2000 and more than 10 % 20 years later. Applications of solar heating may develop faster than for instance solar electricity production because the latter implies a higher technology and hence a longer development effort. In the long run, however, the contribution of both may be equally important.

It is generally agreed that an EC solar energy programme must have a view on the export markets as well. The potential for market penetration is closer in the sunny countries where solar energy fits particularly well in modern schemes of decentralized development, a fact which should also be seen in the light of the cooperative programmes between the EC and the third world.

II. OUTLINE AND STATE OF PROGRESS OF THE FIRST PROGRAMME

The first programme covers the broad spectrum of solar energy technologies for thermal energy production, electricity generation and photosynthetic conversion. The total budget is 17,5 MEUA. This programme can be considered as having fully reached its objective to initiate, stimulate and strengthen solar energy R & D activities in the Community and especially in the following fields:

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Project A (Solar Energy Applications to Dwellings)

- Several types of heat collectors are being tested in a coordinated effort of 19 Laboratories in order to develop commonly agreed methods for performance rating.
- Construction of several solar houses in the member countries has been supported with small funds. Data on all existing solar houses in the EC are presently collected with an eye to a coordinated effort on monitoring their performances.
- A solar heating manual for the public is under preparation.
- Models are developed and validated by means of test rigs for full-scale solar heating systems for houses.
- Storage systems are developed for solar heat at low temperature.
- Research work has been initiated on solar cooling technology.

Project B (Thermo-mechanical Solar Power Plants: The Helioelectric 1 MW el. Power Plant)

The design and construction work was officially started in November 1977. Since that time, the construction site has been selected in Sicily and first prototypes of components developed. A model of the receiver is already being tested at the solar plant near Genoa, Italy. The two types of heliostats, which will be employed, i.e. a French and a German one, are being tested during the summer of 1978.

The plant is expected to be completed at the end of 1980.

Project C (Photovoltaic Power Generation)

A very comprehensive development programme on solar cells and photovoltaic generator systems is under way. It includes 50 single actions. Silicon and other types of solar cells are being developed with the aim of decreasing their cost by at least one order of magnitude. Optical concentrator systems for solar cells are also investigated. Several prototype generators in the kW range are being erected in several climates of Europe. A 1 MW photovoltaic power plant is investigated with a preliminary feasibility study. In September 1977, the Commission organized the very successful First European Photovoltaic Solar Energy Conference (470 participants). The second Conference will be organized in Berlin (West) in April 1979.

Project D (Photochemical, Photoelectrochemical, Photobiological Conversion)

This project includes currently 34 research contracts with most of the outstanding European laboratories in this field. The type of research is fundamental and results with an energy impact are expected in the long range only.

Project E (Energy from Biomass)

Millions of tonnes of organic wastes remain currently unused in the EC. In order to enable their conversion for energy purposes gasifiers or fermenters are developed or improved, aiming at the production of convenient fuels.

Short rotation forestry on marginal land and algae farm schemes for energy production are investigated experimentally and theoretically.

Project F (Solar Radiation Data)

This project is implemented in cooperation with the different meteorological services located in the EC member countries. An European solar radiation atlas is under preparation. The existing measuring network is improved and methods for the exploitation of satellite data are developed.

In conclusion, the important role of the EC programme as a platform for exchange of experience and cooperation among european engineers and scientists should be emphasized. As a rule, the Commission staff organizes each year about a dozen coordination meetings in various places in the member countries; these meetings are attended by the contractors and the corresponding expert groups set up for each of the EC solar energy projects.

III. THE SECOND R&D PROGRAMME

III. 1. Rationale and General Outline of Proposed Activities

It must be stressed how important the general energy sector weighs in the European economies of today in terms of investment and development. Correspondingly, a new energy may play some role in the energy scenario only if its development effort reflects its expected impact. This rule is readily applied for nuclear and fusion energy; it holds also true for solar energy for which the development effort should continue to increase rapidly, in pace with its increasing promise.

In the present draft, the funding has been increased with respect to the first programme. The first phase of the first solar energy programme was exploratory and the second phase is more representative for a suitable rhythm of the programme. In the current second phase, the yearly contact expenditure is approximately 8 MUA which corresponds to a budget of 32 MUA in 4 years. Keeping in mind that the second programme should cover the period 1979 to 1983 in which solar energy will be the subject of major efforts worldwide, it seems reasonable to further increase the rhythm of the Communities' effort beyond that of phase 2 of the first programme. The increased expenditure will be required, indeed, to keep track with the higher cost of hardware studies and the pilot installations necessary before entering into a possible demonstration phase.

It would be misleading to take the over all budget of the current programme as a strong reference because this first programme and its budget were prepared in 1974/75 when solar energy was still a subject of less interest than today; since that time also money has been devalued by inflation.

As a result, the over all budget of 58 MUA for the period 1979-83 is the minimum of effort one must credit at this point in time for a relevant energy of the year 2000.

By its physical nature solar energy and its derivates cover a broad spectrum of applications which are included in the programme. Most of the R & D activities of the first programme should be continued. The repartition in 6 projects (A to F) has been maintained. Two new activities have been added. Emphasis is put on projects A, B, C and E which are particularly promising and for which the technological barriers to be overcome are well assessed and present relatively few uncertainties. Despite the fact that solar heating has one of the largest potentials among all solar energy systems, effort on Project A is not the biggest within the EC programme. Here one must take into account the large activities which are already funded by the Member countries themselves so that a funding level of 11 MUA seems reasonable to complement this effort.

The effort in Project B is reasonable bearing in mind that its potential in the northern part of the EC is low but that such systems have considerable export potential. Emphasis in Project B is put on completion of the 1 MW plant.

The budget foreseen for photovoltaic power generation, Project C, is the highest, for several reasons: Project C of the EC programme was already very successful in stimulating activities and programmes in the Member countries so far and a further impetus can be considered beneficial. For solar electricity production photovoltaic conversion is unique in that it is technically viable in all parts of the EC and, while the economic prospects for immediate application in the EC are small, its near term potential for export markets is particularly important. It is generally recognized that there is still considerable room for improvement of the conventional cell technologies and a need to reduce cost of manufactures; many alternative cell technologies are only little explored yet. The construction of prototype power producing arrays has become urgent to gain experience on the system level. It is also considered essential that a significant number of installations be supported in order to stimulate the development of European production.

Project E is kept at an intermediate funding level within the programme. The use of wood wastes and straw is making rapid progress but the concepts of growing biomass specifically for energy use must be investigated with care.

The funding of Project D is relatively low because - despite its promise - it is still a scientific research subject.

The size of the wind energy project is relatively small because it is a new activity.

Solar energy in industry and agriculture should be considered on a low effort to allow assessment studies. This theme may be seen in association with Project A.

Project F is an "horizontal" activity for which the need is obvious.

III. 2. Prototypes and Pilot Projects

In the second EC solar energy programme, more emphasis should be put on the development and construction of prototype systems, to identify possible problem areas involved with systems, to increase the over all credibility of solar energy and to encourage its rapid implementation. This applies particularly in Projects B, C and E.

A prototype is, generally speaking, the first full size realization of a new system which is built to prove the concept. As a rule, after completion of construction it necessitates further adjustments and improvements as well as operational tests and life tests.

The building of a prototype system and its successful operation completes the development work of a new technological concept and opens the way to its industrialization and the start for further development of an improved 2nd generation of systems. Prototypes are of prime importance for defining the choice and optimization of components; they are also the ideal test beds for components. As large full-scale system prototypes they are also important for non-technical reasons. Firstly, they encourage production on an industrial scale and help to decrease costs on the "learning curve". Secondly, as pilot projects they have a demonstration effect. However, prototypes are not pure demonstration projects because of the technical risks they include and the amount of development involved in their construction and operation. Only after completion of construction and test of a significant number of prototypes is sufficient experience gained to start building of projects for pure demonstration purposes.

In the EC, prototypes must generally have a minimum critical size to become credible as a future large-scale energy. The 1 MW size seems appropriate to start with. Such prototypes offer in particular a viable basis to encourage cooperation of industry from different member countries: when realized as cooperative projects they allow joint developments which otherwise would be impossible among basically competing industries. As a result, European companies will be encouraged to specialize in the solar energy sector, and to cooperate efficiently.

The currently built EC helioelectric power plant is an example of such a scheme of European cooperation which already proved successful.

In the second programme, the construction of prototypes should be enlarged to other fields such as:

Project A: EC participation in a number of solar heating systems for community buildings and villages

Project B: completion of the 1 MW thermo-mechanical plant

Project C: building of a total of 2 MW photovoltaic capacity, half of it in northern Europe, the other in southern Europe

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Project E: set-up of a large integral biomass project using wood including all steps from production and harvesting wood in a forest to conversion and utilization

Project G: set-up of a larger wind generator system.

III. 3. Combined Projects

It should also be realized that in some cases projects are complementary to other projects of the solar programme or other activities. Examples are the following:

- combination of biomass plantation and wind power generators,
- solar collectors producing both electricity and heat,
- solar heating combined with bio-fuels, heat pumps, geothermal energy, etc.,
- photovoltaic generators combined with wind power generators.

These and other combinations should be further considered in the course of the programme.

III. 4. Funding

	Total MEUA
Project A - Solar Energy Applications to Dwellings	11
Project B - Thermo-mechanical Solar Power Plants	5
Project C - Photovoltaic Power Generation	23
Project D - Photochemical, Photoelectrochemical, Photobiological Processes	3
Project E - Energy from Biomass	10
Project F - Solar Radiation Data	2
Project G - Wind Energy	3
Project H - Solar Energy in Agriculture and Industry	1
Total	58

	TOTAL	1979	1980	1981	1982	1983
MEUA	58	3	26	16	10	3

IV. DETAILED DESCRIPTION

IV.1. PROJECT A : SOLAR ENERGY APPLICATION TO DWELLINGS

IV.1.1. INTRODUCTION

This programme is directed mainly towards the development, in the short and medium term, of technologies appropriate for use in Europe, where heat storage is in particular a key problem. Solar cooling has a potential for export, and, later, for use in southern Europe.

It can be credited to the merits of the first four-year programme that besides its contribution to the European technical research and development in the field of Solar Energy Applications to Dwellings it has also served to clarify the tasks which lay ahead. A start to tackle some of the immediate tasks, e.g., the test of collector and system performances, in particular the validation of solar heating system models, has already been made during the first four-year programme, for others, e.g. the investigation into the durability and long term performance of solar collectors, the time seemed not yet ripe.

It is evident that in the new programme a number of investigations will enter the pilot stage. The fact that pilot facilities and prototype studies are expensive is reflected in the proposed budget.

In addition to the effort on currently prefered systems and system components - a house with a roof mounted collectors employing a water fluid is a characteristic example - due attention should be given to 2nd generation systems implying integrated concepts and more advanced technologies.

Solar heating and cooling applications in industry and agriculture may be considered as an extension of solar applications in habitat. Energy consumption in industry involves a relatively large fraction of "high temperature" heat above 100°C and the types of heat applications differ marketly from those in habitat. For both reasons, possible solar heat applications in industry and agriculture require first and foremost careful assessment and implies a new kind of competence.

IV.1.2. OBJECTIVES

The objectives for the new programme on Solar Energy Applications to Dwellings are obviously subordinated to the overall objective of the Energy R&D Programme i.e. to stimulate the R&D in the field of energy and to improve the coordination and collaboration of the activities of the member countries in this area.

The general objective of Project A is twofold:(1) to support the implementation of first-generation solar heating systems of the conventional type through extensive system studies and tests, (2) to investigate new technologies and integrated concepts for "2nd generation systems" such as air-fluid systems, community dwellings and villages, low-energy systems and new concepts to combine active and passive heating systems, high-temperature collectors, seasonal storage and others.

These objectives include the following tasks :

- development of economically and technically acceptable solar heat storage systems with the emphasis on long term storage;
- development of solar heating systems for dwellings with the aid of solar pilot test facilities and by evaluation of the existing information from solar houses to arrive at suitable formulas for solar heating system designers;
- development of test procedures for the performance and durability of solar flat-plate collectors;
- continuation of the research and development in solar cooling and the combination with solar heating systems;
- assessment of community heating schemes, problems related to the introduction of solar energy in the building industry, maintenance problems etc...

IV.1.3. PROGRAMME DESCRIPTION

IV.1.3.1. Heat storage

The success of the introduction of solar energy for space heating depends largely on the solution of the storage problem. Cheap and long term storage of solar heat has, therefore, been recognised as a key area on which to concentrate R&D. The research will not be restricted to one family dwellings only, but will include heat storages for large solar heating systems e.g. for apartment blocks and other groups of dwellings.

The programme on heat storage can be subdivided into the following areas :

- Studies of selected heat storage systems in pilot plants with simulated and programmed heat input and heat extraction for both water and air systems.
- Testing of promising heat storage systems linked to the existing solar pilot test facilities for heating systems.
- Continuation of the R&D of the different heat storage systems on a laboratory scale e.g. systems using latent heat, heat of chemical reactions, heat of adsorption, etc...
- Specific heat storage applications (storage in building materials, combined collector - storage systems etc..)

IV.1.3.2. Solar Heating Systems

The working areas for this part of the programme follow logically from the first programme, where the validation of solar heating system models with the help of solar pilot test facilities had just started for systems using a liquid as heat transfer medium and where a beginning had been made to study the problems related to the installation, control and maintenance of solar heating systems in actual buildings. Due attention should also be given to the problem of cost of installation of collectors and the regulation of systems. Hence efforts to standardize equipment and thus their production cost should be supported. In addition to flat plate collectors, the testing and application of focusing collectors suitable for house heating should be included for support, but, the development of focusing collectors is outside the scope of this programme. Specific areas of activity are :

- Continuation of the validation of solar heating system models with the existing Solar Pilot Test Facilities for systems using a liquid as heat transfer medium.
- Validation of solar heating system models with Solar Pilot Test Facilities for systems using a gas as heat transfer medium.
- An experimental study of the relative performance of different solar heating systems.
- A study of the problems related to the installation, regulation and maintenance of solar heating systems in actual buildings mainly by evaluating the observations made in existing solar houses.
- Development of test procedure for field tests of the performance of solar heating systems.

IV.1.3.3. Standard test Procedures for solar collectors

A fruitful collaboration between 20 European organisations dealing with this subject has been set up during the first 4-year programme on solar energy. Collector testing is also part of the direct programme; the JRC in Ispra is building outdoor and indoor test facilities. The activities in Project A, however, are intended to provide the necessary complement from research laboratories in the member countries. The collector testing activity within the current programme is extremely successful although it restricts itself to coordination of laboratories and requires a very small budget. This activity should be continued in the second programme on the same basis, such as :

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- Further development of the performance tests for solar collectors.
- Development of test procedures to examine the reliability of the performance and the durability of solar collectors.

IV.1.3.4. Solar Cooling

- Development of absorption and Rankine cycle machines and the comparison of their performances.
- Research and development on new absorbant/refrigerant combinations, solid adsorbants etc. ..
- Development of high efficiency collectors.
- The installation of a small number of solar cooling trial rigs to test components and solar cooling system models.
- Development of combined solar heating and cooling systems.

IV.1.3.5. Introduction of Solar Energy as an integral part of habitat

Some problems regarding the solar energy application to dwellings are best studied in a more general setting. Solar heat applications in habitat are indeed closely associated with general building problems as for instance architectural design, retrofitting in some cases, insulation schemes, heating with heat pumps etc...

The passive heat collector which may be used to replace a regular wall and raises an integration and regulation problem is a good example to demonstrate this. In any case there are so many design variations possible that the EC programme should not aim at gaining experience independently but rather participate in some of the numerous solar heating projects which are under way or being initiated. In this way, local projects can be implemented to the benefit of the whole Community . The EC programme should encourage the formation and collaboration of mixed groups of engineers, architects and urbanists. This also would serve to strenghten the link with national activities on the same subject. The contribution of the EC programme should put emphasis on instrumentation, monitoring of the buildings, and the analysis of data. All these projects in which the Commission should have an interest require a separate treatment and should therefore be brought together in this part of the programme. Examples are :

- the study of problems related to the introduction of solar energy in the buildings industry;
- the study of maintenance problems;
- solar energy and architecture.
- the specification of performance monitoring standards of solar heating and solar cooling systems.

IV.1.4. FUNDING

	TOTAL	1979	1980	1981	1982	1983
MEUA	11	0.5	5	3	2	0.5.

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IV.2. PROJECT B : THERMO-MECHANICAL SOLAR POWER PLANT

IV.2.1. INTRODUCTION

Within the design and construction phase of the 1MW Helioelectric Power Plant which was started in the first programme, sound and fruitful cooperation between the industrial partners from the Member countries participating in the project (D, F, I) has already been achieved and is encouraging for future work. The content of Project B in the second programme as outlined below is by and large a follow-up of these current activities.

In the MW range, it seems that the most practical way of thermo-mechanical solar energy conversion into electricity is the power-tower concept : mirrors installed on the ground reflect and concentrate the sunlight on a central receiver mounted on top of a tower. A working fluid is heated up in the receiver to rather high temperatures ($400°C < T < 950°C$) and drives a turbo-alternator. Water, gas and liquid metals are the most common heat transfer fluids.

Power-tower plants can be operated in the southern countries of the E.C. Export into the sunny devoloping countries may become an important market för European industry.

Further action beyond the first programme is needed to achieve lower costs compatible with market prices of electricity in the European Community.

In the second programme of Project B emphasis should be put on the completion of construction of the 1 MW plant (Phase C), its extensive testing (Phase D) and finally experimentation on the plant of new components in view of a further increase of its performance (Phase E). This activity is to be complemented by the analysis of alternative cycles such as open gas, liquid metal and combined cycles. In view of larger plants which are more than just geometrical extrapolation of the 1 MW plant and require new design schemes, the effort should be limited and concentrated on preliminary design and study of advanced components.

It is important to note that in future activities of Project B the largest possible participation from all Member countries must be encouraged and stimulated.

IV.2.2. OBJECTIVES OF A NEW PROGRAMME

1. Demonstration of the viability and the potential of the power-tower concept for electricity production.

2. Optimization of the power-tower concept by assessment of alternative technologies and cycles.

3. Design of larger systems with a view to cost reduction.

IV.2.3. SCOPE

1. Completion of the construction of the 1 MW Pilot Plant which was started in the first programme. Testing, operation and optimisation of the plant.

2. Evaluation and development of other technologies/cycles (in particular the gas cycle) which might become interesting alternatives to the presently developed steam cycle. Design and even hard-ware construction of some components may be initiated if the situation is ripe enough to do so.

3. Preliminary design of a larger plant in the 10 MW range of higher cost-effectiveness.

IV.2.4. DESCRIPTION

1. The contract of the 1 MW Helioelectric Power Plant foresees that at the end of the first four-year programme, the detailed design will be completed and the construction under way. Within the second four-year programme, the plant construction should be completed by the end of 1980. It will be followed by a testing period of 1 to 2 years and a subsequent optimization phase. It is obvious indeed, that the plant will need adjustment and optimization during the test period, since it is the first prototype of its kind. This testing and optimization may comprise modifications of the components and sub-systems. Modifications may become important especially in a subsequent phase, foreseen in the contract, which allows the Commission and industry to continue R&D work with the plant.

2. In order to improve the performance and cost-benefit of helioelectric power-tower plants, complementary technologies and cycles should be investigated. The choice of other technologies and cycles calls for technical and economical evaluations and trade-off studies to find out the most appropriate system compatible with the power-tower principle. Hand in hand comes information input from design and first experiences of the 1 MW plant which becomes available by that time (from 1979 on), so that a reasonable choice can be made.

   At this moment, the gas cycle seems to be the most interesting alternative with respect to the steam cycle. Open-cycle gas turbine plants need no refrigeration which is an extra benefit in remote and sunny areas where the provision of cooling water may be a problem.

   Mixed cycles may have even higher efficiencies than pure gas cycles. This is important in view of a possible reduction of the area of the cost intensive mirror field. In any case, the change of the thermodynamic cycle implies a new lay-out of the field of heliostats because, for a fixed power, the receiver area will differ from one cycle to the other as a result of the different heat transfer properties of the working fluids.

   The projected work within this second four year programme would include concept studies on cycles other than steam cycles, investigations on the main lay-out parameters and of some critical components.

3. Although solar power plants are essentially bi-dimensional in character, the economy of scale applies to the cost-effectiveness of the thermo-mechanical part of solar power plants. Hence, larger plants of 10 MW or more can be expected to produce electricity at a lower cost than a 1 MW plant. Larger plants should therefore be developed as soon as the fundamental experience has been gained from the construction and operation of the 1 MW plant and new competing power cycles were evaluated.

   The construction of a plant in the 10 MW range has to go step by step. Within this second four year programme, evaluation studies are proposed as well as lay-out work on cycles and may be construction of some components. Start of construction of a 10 MW plant would not be possible within the second four-year programme.

IV.2.5. <u>FUNDING</u>

	TOTAL	1979	1980	1981	1982	1983
MEUA	5	0.7	3	0.8	0.5	-

IV.3. PROJECT C : PHOTOVOLTAIC POWER GENERATION

IV.3.1. INTRODUCTION

In view of their capability to convert also the diffuse part of sunlight, photovoltaic plants are most promising devices for producing electricity from solar radiation in the relatively unfavourable climate of the EC. To our present knowledge, photovoltaic conversion is the only reasonable way to produce solar electricity in the northern parts of Europe.

At the present time it is to early to speculate to what extent and in which time span photovoltaic energy may play a role in Europe for electricity production on a large scale. The reason is that it is too new. But extrapolating from the tremendous progress achieved in recent years one is led to consider that in the long run its potential as an energy source for Europe is a real one. In the meantime there are good reasons to develop solar generators for local uses in Europe for agriculture (irrigation ....), telecommunications, etc. and to assist the European industry to become competitive on the newly emerging export markets.

The favourable response to the EC Photovoltaic Solar Energy Conference (September 1977) and the large interest encountered by the first EC four-year solar energy programme in the European industry and public research institutions reflect the steadily increasing awareness of the potential of photovoltaic solar energy for the EC.

In the first four-year programme emphasis is put on the improvement of the existing technology (cost reduction of the silicon material by using different methods and by automating parts of the process), on low cost thin film techniques for silicon cells (polycrystalline material obtained in different ways), on GaAs and Si cells for use of light concentration, on different concentrator systems, on encapsulation materials (plastics and glass) and encapsulation techniques and on alternative materials (CdS, CdTe, CdSe, amorphous silicon). In the second phase a start was made with system studies for a 1 MW module of a power plant, and several small systems (up to 5 kW) are built for specific applications.

Since the beginning of the first four-year programme several important results are obtained. The research efforts and a partial automation already resulted in a cost reduction of silicon photovoltaic panels by a factor 3 to 4. Without assuming a technological breakthrough a further price reduction by a factor 4 can be predicted with certainty within the next 5 to 7 years. Using light concentration with passive cooling the price of electricity generated by photovoltaic panels can additionally be reduced by a factor 1,5 for Northern Europe and by a factor 2,5 for clear sky countries. An increase in efficiency of the panels will yield a further price reduction. Depending on the relative cost of the photovoltaic panels and of the concentration system and depending on the relative proportion of direct and diffuse light, larger concentration factors and use of active cooling and two dimensional tracking can results in more economical systems, certainly when the dissipated heat is also used.

Due to these price reductions the number of applications where photovoltaic panels can be used in an economical way is increasing fast. A rechargeable battery charged by a photovoltaic panel is already today in most cases more economical than a dry battery. In this category of applications we find all small power systems where an independent energy source is required for safety purposes or where no conventional electricity is available. A more important market now opens for independent electricity generators of a few hundred watts to 1 MW, where the electricity is now produced by diesel generators. For systems with a high load factor, photovoltaic panels <u>with concentration</u> are already economical today if no storage of electricity is needed. Photovoltaic panels <u>without concentration</u> will be competitive with diesel generators within 5 to 7 years. The most interesting large scale application is water pumping for irrigation purposes.

Photovoltaic conversion will have an impact on the energy production in the EC countries, only when residential applications (electricity production for houses and buildings) and central power applications become economical. A satisfactory solution to the storage problem also has to be found. There is a tendency to go to larger (nuclear) units for electricity generation; these units need large base loads to be economical. A combination of such units with a grid of distributed alternative power stations for intermediate and peak power is an interesting solution. It is often claimed that storage could be avoided by linking the alternative units with the base load utility grid, however the demand for a high base load will not be satisfied due to rapid and unpredictable changes in the climate of most parts of Western Europe. Short term storage therefore will be unavoidable and is technically feasable using batteries. Long term storage can be avoided in many locations by combining photovoltaic and wind systems. In Western Europe there indeed are many locations where the seasonal dependence of wind and sun are about complementary. A realistic alternative residential system which could be important in the intermediate term for many locations in Western Europe could consist of a photovoltaic unit, a wind generator, short term storage (batteries) and a conventional back up generator. In most parts of Europe a photovoltaic power plant will in the long run also be more suitable than a thermomechanical solar plant, because of the amount of diffuse light, because the economics of a solar thermomechanical plant is only reasonable for large units, and because photovoltaic panels are static and virtually maintenance free and they can be integrated better into the landscape. Hybrid panels (photovoltaic panels combined with heat collectors) are more economical for residential applications when the dissipated heat is used for heating. Because of the storage problem, the combined wind-photovoltaic system is more economical than the only wind system, for many locations in Europe.

Taking these considerations into account, it is not surprising to see an increased interest of the European industry. Already 17 companies are involved in the first EC programme. US companies start production of solar cells in Europe and several oil companies and battery manufacturers get interested in photovoltaics. To have as soon as possible an impact on fuel import and on energy production in the EC it is important that the process of cost reduction is as fast as possible. This goal can be reached only by building and developing a European industry which is in the beginning based on the market in the Southern part of Europe, in the Arabian countries and in developing countries. A larger industrial interest and a larger production will decrease the prices faster and speed up the economical use in the EC countries.

The construction of a 1 MW photovoltaic plants is particularly attractive for the following reasons :

- remain in pace with current international developments where the critical unit size of plants is growing very rapidly : in 1976, the biggest photovoltaic generator world wide had a power of 3 kW, in July 1977, the maximum unit power was 20 kW, the construction of several plants of 300 kW and more has recently been started in the USA.

In contrast, by building a larger number of smaller units in the 100 kW range instead there is a risk of dispersion of effort

- a large 1 MW unit is particular suitable to encourage or strengthen cooperation among European companies in the photovoltaic sector, a highly important purpose which can best be achieved within one large single project;

- assess the required technologies for structural support of the arrays, power handling equipment, storage and connection to a national grid and open the way for further specific developments;

- employ the plant as a test bed for various components. New types of cells and systems such as amorphous silicon cells, CdS cells, focusing collectors for GaAs cells etc. can be included in the plant and tested in comparison to conventional cells;

- allow comparison in operational conditions of a photovoltaic plant and a thermomechanical solar plant of the same size with a view to investment and operational costs, performance, maintenance etc., only in this way will it be possible to collect the necessary information about the future prospects of both technologies.

IV.3.2. OBJECTIVES

1. Continued R&D effort on solar cells and arrays as started in the current four-year programme with the aim of reducing costs and increasing the life-time.

2. Design and construction of a family of autonomous photovoltaic power systems with a total power of 2 MW. This could include the detailed design and the construction of an intermediate - size experimental central power plant of 1 MW.

IV.3.3. SCOPE

1. Improvement of current silicon cell and array technology and methods to automate the production processes.

2. Development of reliable concentration systems.

3. New semiconductor materials and cell structures.

4. Identification of autonomous photovoltaic systems in the 5 to a few hundred kW range. Development of associated technologies (storage, power conditioning) .

5. Set-up of a family of autonomous photovoltaic systems in various EC climates and monitoring of their performance.

6. Development of a 0.5 to 1 MW central power plant to be connected to a national network.

IV.3.4. DESCRIPTION

1. R&D effort on solar cells and arrays

In order to achieve the intermediate price goals,research on the improvement of the existing silicon technology, on automation or production and on encapsulation will remain necessary. With a decreasing price of the cells, the price of the module materials becomes more important and these materials must also be studied.

Although a choice among the different methods of producing polycrystalline materials cannot be made yet, it is expected that within two years the best suited candidate will be known. Research on the improvement of this technique will be required.

Concentration is believed to be an important method for reducing the cost of photovoltaic generators, as long as the cost of the cells is high. Studies on concentration with low and high concentration ratio therefore have to be included.

In order to achieve the long term price goal it is essential to study other materials (CdS, CdTe, CdSe, amorphous silicon, GaAs etc.). The best choice between these candidate materials can probably be made within a few years; as a result, further research will be conducted on a restricted number of candidate materials, and on a limited number of specific properties and fabrication processes.

The programme will be held open to new ideas on cells and materials.

2. Design and construction of autonomous systems with a total power of 2 MW

This action, started in the second phase of the first programme must receive full attention, since it will provide the potential users and manufacturers with the basic data pertaining to photovoltaic applications.

The aim is to build a family of photovoltaic arrays with a total power of 2 MW, of which half should be installed in the Northern part of Europe. These arrays will be used in small installations of 5 kW to a few hundred and also in a central power plant.

The small autonomous systems will be installed in various locations and for specific applications. Very valuable information and experience will be gained along the following lines :

1. Assessment of specific applications and their constraints
2. Installation of pilot units in different geographical locations for several applications.
3. Combined systems with wind generators, thermal collectors, etc.
4. Determination of the storage capability required for several specific applications and storage techniques.
5. Evaluation of characteristics of DC/AC invertors and power control devices.
6. Full assessment of systems using concentrators and study of the related problems.
7. Encapsulation techniques for high reliability and extended life expectancy of solar array modules in different climatic areas.
8. Determination of the environmental impact.
9. Assessment of the economical potential for future energy senarios in Europe and in the short term for the expert market.
10. Assessment of institutional and legal matters preventing or encouraging a wider spread of applications.

The design study about the 1 MW power plant, conducted during the first programme will provide the necessary ground to determine the characteristics of an optimized plant which could be erected in the next four years. This decision should eventually be taken when the design studies which are under way will be completed. (First half of 1979).

In view of the fact that photovoltaic central power plants of 100 MW or more can be envisaged, a 1 MW plant can be seen as the smallest module of such a large plant. The size of the 1 MW plant will provide a good basis for comparison with the thermodynamic solar power plant as constructed in Project B. In particular, it will be worth comparing the construction cost and the operational performance and costs of both plants.

A 1 MW plant will give an insight in specific problem areas associated with size and to develop the needed technologies to solve them, in particular for the outline of the busbars, the management of power and voltage, installation of panels on the ground and their electrical interconnection, connection to the utility grid, storage etc. It will allow a comparison between flat plate photovoltaic panels and use of concentration. The relative importance of the cost of the installation and the cost of the panels will yield important information about the minimum efficiency required of the panels. The plant will also provide important operating parameters e.g. on reliability, maintenance, lightnings and thunderstorms, environmental impact, hazard problems etc. Only by the construction of such a full scale 1 MW module will it be possible to prove the viability of photovoltaic conversion on a large scale and to determine its operational parameters in comparison with conventional plants, as a peak or intermediate load capacity .

In a later stage, this 1 MW power plant could be the start of a photovoltaic centre where new photovoltaic panels could be integrated and tested.

A 1 MW project is by no means premature. It will not present any technical risks and in addition, the relative large demand for photovoltaic arrays will give the incentive to European manufacturers to improve the productivity of their processing techniques. As a results, the cost of photovoltaic devices will decrease, and the competitivity of photovoltaic plants for specific applications will be even greater.

IV.3.5. FUNDING

	TOTAL	1979	1980	1981	1982	1983
MEUA	23	0.7	13.2	4.9	2.4	1.8

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IV.4. PROJECT D : PHOTOCHEMICAL, PHOTOELECTROCHEMICAL AND PHOTOBIOLOGICAL PROCESSES

IV.4.1. INTRODUCTION

The production of hydrogen, or other fuels, by photochemical photo-electrochemical or photobiological dissociation of water is one of the most attractive possibilities for the utilization of solar energy.

More than 30 research laboratories in the EC are involved in the first four-year programme. It was generally agreed that the work performed thus far was outstanding.

The work should be carried on during a second four-year programme : rapid breakthroughs cannot be expected yet because this project is the beginning of a new kind of research including such advanced areas like microbiology, this research being mostly fundamental.

IV.4.2. OBJECTIVES

The general objective is the study in natural and synthetic systems of oxidation-reduction reactions across membranes and photolysis of water to produce hydrogen or other fuels. It includes the following areas :

1. Understanding of the photoconversion mechanism
2. Photochemical production of fuels and/or electricity
3. Improvement of hydrogen production via living cells
4. Construction of artificial systems based on photosynthesis models.

IV.4.3. SCOPE

1. Conversion of light into electricity and/or hydrogen by photochemistry e.g. in semiconductor/electrolyte cells.
2. Biological hydrogen production in algae and bacteria, including genetic adaptation and selection of new types of organisms and species.
3. Conversion of light into hydrogen, other fuels, or organic matter : study of photosynthetic membranes, enzymes and their incorporation into matrices.
4. Construction of artificial systems by modelling of biological systems.

COMMENT

The scientific content should be basically the same as in the first four-year programme. The effort on fundamental research should be kept at a constant level. In addition explicit efforts will have to be made towards the analysis of potential applications and the construction of a proof-of-concept model and a pilot system for continuous hydrogen or electricity production. This eventually would allow to start evaluation on thermodynamic efficiencies and enzyme kinetics. Exchange of young scientist between the laboratories in the member countries should be further encouraged.

FUNDING

	TOTAL	1979	1980	1981	1982	1983
MEUA	3	0.4	1.5	1.1	-	-

IV. 5. PROJECT E: ENERGY FROM BIOMASS

IV. 5.1. INTRODUCTION

The purpose of Project E is to demonstrate the potential of the energy from biomass concept for Europe. Undeniably, biomass is most important for non-energy purposes for which it has priority. But the fact remains that for instance large quantities of straw each year remain unused in Europe. Even wood, of which large quantities worth 6,000 MUA are imported each year in the EC is a potential energy source of the future. It is meaningful, for instance, that 25 % of the forests in France are currently underexploited and all wood residues unused.

The processes which will emerge to grow and use biomass for energy, in particular the conversion processes should also be considered in the light of export markets as they have an obvious interest for the agricultural economies of developing countries.

The experience of the last few years, both as a result of the European Community's first four-year programme and of the efforts employed elsewhere, has already resulted in a heightened awareness of the possibilities which exist for the exploitation, for energy purposes, of biomass, either in the form of existing or predicted organic residues or of crops grown specifically for this purpose.

In the second four-year programme, activities of the first programme are intended to be continued and strengthened in particular (1) the use of straw and wood wastes,(2) conversion processes such as pyrolysis and fermentation, (3) biomass production such as short-rotation forestry and algal farm schemes. These activities aiming at the production of convenient fuels for European needs are competing with other uses of biomass outside the energy sector e.g. the production of single-cell proteins, paper and construction materials. The interfaces between various types of utilization are being well assessed in the current first programme and will serve as guidelines for futures studies.

The second programme will culminate in a small number of large integrated pilot projects in the forestry area. These pilot projects should follow the following scheme:

- they should be a sink for wood and other biomass
- they should be preceeded by intermediate size projects
- they should possibly combine other uses of wood than for energy
- they should be as relevant as possible for Europe and be implemented in several typical European climates and soils
- various production schemes namely coppicing should be considered

IV. 5.2. Objectives

1. To assess the present and future contribution of Energy from Biomass in the European region

2. To assess the technical and economic feasibility of various concrete Biomass/Energy concepts in the European context

3. To promote the exploitation of feasible Biomass/Energy concepts within Europe.

IV. 5.3. Scope

1. Identification of amounts and distribution of organic residues suitable for energy conversion and determination of the costs associated with the use of such residues for energy purposes

2. Identification of suitable energy crops which can be grown on a significant scale in Europe and can make a significant contribution to energy availability at economic cost

3. Detailed systems analyses of concrete Biomass/Energy concepts of interest to Europe

4. Determination, by experimental efforts, of the values of various parameters necessary for the satisfactory undertaking of the systems analysis

5. Technological development of conversion processes which are seen to be of relevance to the successful implementation of envisaged Energy/Biomass concepts

6. Execution of pilot projects aimed at:

   (a) validating systems studies

   (b) identifying areas for further research and technical development

   (c) accelerating the processes leading to the commercial exploitation of the concepts

   (d) establishing the credibility of the concepts both in the public consciousness and at the level of national administrations.

5.4. Description

1. Assessments and studies

The following proposed actions will largely follow as a result of the preliminary investigations carried out under the first programme. It is already clear that projects should be envisaged in the following areas:

1.1 General studies of, for example, the following nature:

- site specific studies of the use of existing organic residues in a well defined region for energy purposes, "self-contained farms"
- studies of the competition between the use of biomass for energy purposes and its use for other purposes
- preparatory studies aimed at identifying new concepts.

1.2 Further investigation of the use of straw and wood wastes.

1.3 Production of fuels from biomass: mixing with conventional fuel liquids, pyrolysis and gasification, fermentation of wet biomass of high water content.

1.4 Sylviculture. Experimental studies of different wood species for different types of soil. Design of a small number of projects associated with certain European regions and climates namely for different broad-leaf species.

1.5 Growing of algae. Assessment of their potential for the production of fuels.

2. Pilot project

The pilot project intends to identify possible new ways of exploitation for energy purposes of large areas of forest which is currently not used. It includes all steps from production, harvesting to conversion and utilization and in particular the following:

- cost effective way of wood cutting and the associated machinery
- collection and further mechanical transformation
- local or central conversion into liquid and gas fuels

Comparative cost analysis and social-economical evaluation will be prime parameters to be considered.

Existing operations for non-energy purposes such as large plants for charcoal or paper production will be taken as a basis for the design and implementation of some of the pilot projects.

IV. 5.5. Funding

	Total	1979	1980	1981	1982	1983
MEUA	10	0.3	2	5	2	0.7

IV. 6. PROJECT F : SOLAR RADIATION DATA

IV.6.1. INTRODUCTION

The availability of reliable and accurate solar radiation data in a convenient form for the whole area of the EC is of fundamental importance for any utilization of solar energy now or in the future.

Presently, the radiation data network is still incomplete or equipped with inaccurate instruments.

Furthermore, the produced data are not accessible in a convenient way for all interested users and engineers.

In the first four-year programme, all eight Meteorological Services in the EC and some outstanding research laboratories have been involved. As none of the actions initiated so far will be completed by the end of this programme, it is necessary to continue these actions and to extend them, e.g. to local microclimates and to specific needs in some areas of use namely biomass production.

Data on wind energy should also be included in future activities because they are not only important for aeolean energy development but also for the operation of solar energy systems such as solar heat collectors and photovoltaic devices employing concentration.

IV.6.2 OBJECTIVES

The general objective is an extension of the objective of the first four-year programme. They are the following :

1. Coordination of national radiation services in particular for the calibration of instruments and the improvement of the measuring network.
2. Production of atlases and data books for the most relevant radiation parameters.
3. Diffusion of data.

IV.6.3. SCOPE

1. Organization of measuring campaigns for the EC national weather services in view of regular calibration of standard instruments.

2. Further development of calculation methods for radiation data on inclined surfaces and for data above certain intensity thresholds and their duration.
3. Updating and formulating of comprehensive radiation data. Publication of an EC radiation atlas and data books. Preparation of reference years.
4. Improvement of the radiation measuring network : including replacement of inadequate equipment and installation of additional equipment.
5. Investigation of local microclimates.
6. Specific measurements for particular areas, e.g. the production of biomass.

IV.6.4. DESCRIPTION

1. A first measuring campaign to calibrate national standard instruments was organized in 1978 and is thougt necessary to be repeated in regular intervals.
2. The calculation methods for inclined surfaces should be completely developed and validated experimentally. The methods should then be applied to produce relevant data for inclined surfaces from measured data. At the same time methods to produce data above certain intensity thresholds including their duration and frequency distribution, for horizontal and inclined surfaces, should be fully investigated and applied. The problem of correlation between the variations of solar radiation and temperature (important for solar heating) should be studied.
3. Radiation data for horizontal and inclined surfaces should be published in the form of an EC radiation atlas. Data for intensity thresholds should be published in appropriate graphs or in data books. Reference years should be prepared.
4. The measuring network should be further imporved and densified so that reliable data can be produced for all regions of the EC. (Including simultaneous data acquisition).
5. Particular attention should be paid to local microclimates and to areas with strong climatic gradients such as mountains and the coast. Under microclimate is understood here a particular local climate on the scale of square kilometres which differs marketly from the climates of the surrounding areas.
6. Exploitation of satellite data to obtain information on insolation.
7. Specific measurements include the following :
   - research on spectral measurements, (for photovoltaic, thermal and biomass applications)
   - measurement of terrestrial (infrared) radiation, in particular (downelling) atmospheric radiation (for biomass production and others e.g. solar cooling).
   - measurement of wind data. They are important not only for the application of wind generators but also for the determination of the cooling effect of wind for all solar collectors.

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- measurement of instantaneous direct solar radiation at regular intervals for the determination of the total turbidity factor.

IV.6.5. FUNDING

MEUA	TOTAL	1979	1980	1981	1982	1983
	2	0.4	0.6	0.5	0.5	-

IV.7. PROJECT G : WIND ENERGY

Possible areas for future research in the EC wind energy programme are the following :

- site evaluation
- wind turbines with an increased power coefficient : development of new concepts involving megawatt-size machines
- development of new machines such as the Darieus rotor and their test under the conditions of Europe and the developing countries
- mechanical-electric conversion systems and connection to utility grids : development of ways to ensure high-quality electricity production and to minimise losses
- use of autonomous wind generators for heating and electricity production in houses
- storage systems for different wind energy applications
- study of wind generators combined with other systems e.g. photovoltaic generators and biomass production plants.

FUNDING

MEUA	TOTAL	1979	1980	1981	1982	1983
	3	-	0.5	0.5	2.0	-

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IV.8. PROJECT H : SOLAR ENERGY IN AGRICULTURE AND INDUSTRY

IV.8.1. INTRODUCTION

As the transparency of the needs for low enthalpy heat in agriculture on a European scale is bad and the situation in industry is even worse the necessity for assessment studies is obvious. At the same time it is clear that both branches will eventually use the same components as compared to solar heating systems in dwellings although the size and numbers differ due to a different energy demand. As the energy needs in industrial processes vary considerably from industry to industry and from firm to firm, in capacity as well as in temperature level, as opposed to the energy needs in agriculture it seems wise to treat these two areas separately. Because of its greater transparency agriculture is listed first although the low-enthalpy heat demand in industry will be a multiple of that in agriculture.

IV.8.2. AGRICULTURE

2.1. Inventory of European farms accordings to :

- type of farming : dairy, crop-growing, mixed
- size : restrict attention to an economic viable size
- climatic region : i.e. with same crop growth rate, harvest time, stabling period etc...

2.2. Assessment of the energy load models for the different types of farms and typical for the different climatic regions.

2.3. Development of solar heating and cooling system models for optimizing the solar equipment.

2.4. Building of prototype solar systems for farms.

2.5. Attention for special aspects related to the introduction of solar energy in agriculture e.g.

- insufficient south-facing roof area to supply the necessary surface for solar collectors
- particular solutions to the storage of solar energy

- construction of certain parts (e.g. storage facility) and maintenance under the farmer's own control
- special solutions for the heating problems of poultry farmers, cattle and pig breeders, greenhouses, etc....

IV.8.3. INDUSTRY

3.1. Assessment of the use of low-temperature and high temperature (>100°C) heat in industry.

3.2. Study of the viability of the use of solar energy in selected branches of industry.

3.3. Assessment of the heat storage requirements for an economic viable solar energy system for these selected branches of industry.

3.4. Prototype studies.

IV.8.4 FUNDING

	TOTAL	1979	1980	1981	1982	1983
MEUA	1	-	0.2	0.2	0.6	-

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GEOTHERMAL ENERGY

CONTENTS

I. INTRODUCTION

Since the energy crisis and as a consequence of the R and D efforts deployed at national and at Community level, geothermal energy has become confirmed as being able to contribute to the Community's supply of energy from indigenous sources in a non negligible manner. However, its potential contribution is in the first instance limited by the following two facts:

a) the necessity of association of a heat source with a water source, water being the heat transport fluid

b) the cost of deep drillings, which is such that exploitation of geothermal energy, even if combined with an aquifer, is economically feasible only at privileged sites (geothermal anomalies).

All geothermal heat extracted within the Community is subject to the above limitations. If it were possible to remove condition a) by fracturing hot dry rocks and injecting water from the surface, geothermal energy could become of much broader interest for the countries of the Community. But even without this, quite some progress has been made in the last two years as regards the search for and the use of "normal" geothermal steam and hot water sources.

The present document summarizes the main actions undertaken in the frame of the first (ongoing) energy R and D programme and presents the progress achieved by these actions. It then outlines the possible content of a second programme which would be the logical follow-up of the first one.

II. OUTLINE AND STATE OF PROGRESS OF THE FIRST PROGRAMME

The first programme was subdivided into five projects:

A - Acquisition and collection of existing and new geothermal data.

B - Improvement of exploration methods.

C - Sources of hot water (low enthalpy).

D - Steam sources (high enthalpy).

E - Hot dry rocks.

Its financial allocation was 13 MUA over 4 years with a staff of 4 posts (2 A, 1 B, 1 C). At the moment of writing this document 119 contracts were signed or committed, with the following distribution:

Project	A	B	C	D	E
number of contracts	35	52	13	11	8

A few more contracts will be allocated in the coming months.

Although the programme still has about one year to go, it will be attempted in the following to describe shortly the main results already obtained or to be expected until mid 1979. More details are given in the following reports:

- First status report (1975-1976) July 1977, EUR 5889
- Proceedings Seminar on Geothermal Energy Brussels, 6-8 December 1977, EUR 5920.

Project A - Acquisition and collection of existing and new geothermal data

An integrated collection of existing geological, geophysical, geochemical and volcanological data has been compiled for specific areas. Reviews have been made of the data available for the Massif Central (F) and the Hampshire Basin (UK). Similar reviews are in progress for Southern Apennine (I) and Rhinegraben (F and FRG).

Temperature data and heat flow data have been collected in all the member states with the ultimate aim to establish temperature and heat flow maps by mid 1979. The drawing of these maps may be terminated in some Member States, but certainly not in all.

Project B - Improvement of exploration methods

Much attention has been attributed to the improvement of exploration methods. Magnetotellurics and electrical soundings have been successfully tested in the area of the Phlegraean Fields (I) and are now tried as a detection method in other areas with a geothermal interest.

Studies to investigate if the seismic velocity is changed when a seismic wave passes through a temperature anomaly are performed in the Urach area (FRG). Theoretical studies were performed to improve the interpretation of magnetic, magnetotelluric and electrical measurements.

Geochemical and isotopic methods have been adapted to local conditions to estimate deep temperatures of geothermal waters and to evaluate mixing schemes of geothermal waters with surface waters. Valuable information about the possible deep temperature in geothermal wells has been obtained.

The development of in situ heat flow measuring equipment has been stimulated.

Project C - Hot water sources (low enthalpy)

The evaluation of the economics of heating systems based on the use of low enthalpy geothermal energy has been supported. The influence of auxiliary heating units, heat pumps, climate etc. has been considered in these studies.

Modelling studies for the estimation of reservoir sizes and for the optimization of production-reinjection doublets are in progress. The chemical consequences of exploiting a doublet in a carbonate basin are being studied. An experiment including the construction of equipment to generate electricity with low enthalpy geothermal energy has been set up with EEC support in Italy.

Project D - Steam sources (high enthalpy)

High temperature and pressure measuring and registration equipment for in situ measurements of temperature, pressure and well diameter are being developed. The probes will be operational at 200 bars and 300°C. The development of drilling muds and cements for high temperature boreholes has successfully been stimulated.

Studies to determine the characteristics of high enthalpy reservoirs at the well head have been supported.

Project E - Hot dry rocks

Preliminary studies to evaluate specific problems linked with the possible extraction of energy from hot dry impermeable rocks have been undertaken. Thermal fracturing of rocks is studied in the laboratory and on models. The propagation of a crack in an impermeable rock is being studied on models as well as in the laboratory.

The possibility of obtaining a multipath connection between two wells is under study.

Studies on a horizontal fracture in rocks at shallow depths are under way to determine the hydrological behaviour of water in a fracture and other phenomena, such as effective heat exchange surface and detection techniques.

III. THE SECOND R&D PROGRAMME

III.1 - General outline

The second geothermal energy programme should be a logical follow-up of the present R and D programme. It should benefit from the results obtained during this programme and continue in those fields where this is justified.

Geothermal energy currently contributes about 450 MW (electrical) and 25 MW (thermal) from hydrothermal sources within Community countries. With a limited life of fossile fuel reserves,geothermal energy provides an "indigenous" source of energy which can contribute to extending the life of natural fuels and which will become increasingly competitive as energy prices rise. In the short term there is a need to develop those sources which can be immediately competitive, such as the low and high enthalpy hydrothermal fields, but the basis must be laid for future developments which could provide an important supplement or alternative to other energy sources.

This would imply tapping those sources which can already deliver energy at competitive prices and carrying out all the work required for developing those sources which might become economic at long range. Geothermal energy can be made available from three different types of sources

- low enthalpy sources (hot water)
- high enthalpy sources (steam, hot brines)
- hot dry rocks.

Low enthalpy sources are in general linked with porous sedimentary layers located at depths down to 3 km. Heat extraction appears not too difficult but unfortunately their economical utilisation is very site specific. The development of the world price of energy is a very important but unpredictable factor to be considered for the economic feasibility of the use of low enthalpy energy.

The exploration for low enthalpy sources should take an important place in this second programme. Information provided by gas and oil prospection should be taken in consideration wherever available. Exploration drillings should be envisaged only after a thorough feasibility study has been carried out showing that exploitation in the investigated area is reasonable.

The use of high enthalpy energy is much less market dependent. Such energy can be converted into electricity thus eliminating most of the transport problems. In the second programme attention also will have to be paid to the exploration for high enthalpy sources. Its occurrence is frequently linked with thermal anomalies, geologically active areas characterised by old or recent volcanism and fractured formations, combined with deep water circulation.

The utilisation of energy from hot dry rocks constitutes an option for the future. Certainly much energy is stored in these rocks, especially at great depth, but the problems to be solved to extract it are considerable.

The proposed programme should concentrate on the study of topics directly related to the exploitation of hot dry rocks, in particular the fracturing (creation of multiple pathways) of large volumes of rock at great depth.

The research and development to be carried out during the second programme should be aimed at indicating whether the production of geothermal energy is feasible in certain areas. Furthermore it should intend to obtain accurate knowledge about the total resources of the EEC in the field of geothermal energy.

The programme should be based on the results of the first research period.

The geothermal data collected during this first period have identified and accentuated some areas where the exploitation of geothermal energy could be a realistic venture. Some of these areas are already known, and here geothermal heat is used successfully (Larderello, Paris and Acquitain basin). Other areas have not yet been fully investigated. Looking for new sites in each country, the situation can be summarized as follows:

Belgium	:	Region North and South of the Massif du Brabant
Denmark	:	Jutland and Sealand
France	:	Massif Central and Rhine graben
Federal Republic of Germany	:	Rhine graben and the Molasse basin south of the Danube
Ireland	:	to be defined
Italy	:	areas within the Tyrrhenian, pre-Apennine belt that extends from Toscany to Campania, Sardinia and Sicily
Netherlands	:	West, Central and North Netherlands Basin, Roerdal Graben
United Kingdom	:	Hampshire Basin, East Yorkshire/Lincolnshire Basin, the Midland Valley and some areas in Northern Ireland.

Research during the next four years should concentrate on these regions, the ultimate aim being to drill an exploration hole. This should, of course, not exclude the continuation of studies initiated but unfinished especially in the field of temperature and thermal flow data collection in other areas.

The research during the coming period should be concentrated on more detailed exploration, on feasibility studies and on the economical aspects of geothermal energy. Basic research will continue however on the level of all new projects to assure a proper scientific backing of these projects.

In order to cope with the new "regional" approach of the second programme a new subdivision into the following four projects is proposed.

A) Integrated geological, geophysical and geochemical investigations in selected areas

B) Subsurface problems of natural hydrothermal resources

C) Surface problems related to the use of hydrothermal resources

D) Hot dry rocks.

The main objectives and the actions resulting from this new approach are summarized below and described in more detail in the attached technical annexes.

III.2 - Project A: Integrated geological, geophysical and geochemical investigations in selected areas

The major objectives of the programme are to collect as much and as precise data as possible on the geothermal resources of the Community and to promote their exploitation by supporting the cost of exploration, including the cost of the first drill hole.

It is intended to undertake exploration by geophysical and geochemical techniques for each area of expected geothermal potential. This work should confirm the features of the areas as possible geothermal fields, and give information about their sizes. The interpretation of these exploration techniques should indicate where an exploration borehole should be located.

Once exploration by surface measurements and temperature measurements in shallow boreholes is terminated, a financial support for the drilling of an exploration borehole is envisaged in those areas where the conclusion seems promising enough.

This support should however be restricted to areas of potential utilisation.

Each prospection project should be open to participation of teams of other Community countries.

A geothermal atlas of the European Community should be drawn up. It should also provide an estimate of the geothermal resources of each important area.

III.3 - Project B: Subsurface problems of natural hydrothermal resources

The techniques to exploit high and low enthalpy geothermal energy have been successfully studied for steam resources in Italy and for hot water resources elsewhere.

There remains however a group of problems to be studied in detail.

Special drilling techniques including drilling equipment, cements and drilling aids that withstand high temperatures are needed.

Current down hole measuring equipment is not designed for temperatures higher than 150°C. It is therefore necessary to develop this equipment for high temperatures and pressures.

Reinjection of used liquids is in general compulsory during the exploitation of low enthalpy sources and hot brines. The problems related to reinjection and in general the problems of reservoir engineering should therefore be studied.

An important parameter in assessing the feasibility of the type of geothermal energy here discussed is the reservoir size. Methods of determining this size should be studied with the aid of models.

III.4 - Project C: Surface problems related to the use of hydrothermal resources

To achieve an economically viable exploitation of geothermal energy sources, it is not sufficient to solve the great number of problems directly related to the subsurface.

Economic evaluations for the use of geothermal energy should be made for several typical areas. As a result of these studies conclusions should be drawn on possible improvements of technology to be recommended. Hardware should be developed only if it is specifically related to the utilisation of geothermal energy.

Attention should also be given to the possibility of using hot brines. The major problem here is to develop the technology and the know how to extract heat from hot brines efficiently and economically while avoiding difficulties due to deposits and corrosion.

The environmental impact of the use of geothermal energy must also be studied and monitored in time. Problems of induced seismicity, subsidence as well as those of the disposal of fluids and salts should be studied.

III.5 - Project D: Hot dry rocks

Studies to promote the extraction of energy from hot dry rocks have been part of the first research programme. The prospect of tapping this immense source of energy is tempting, but the technical problems are enormous. In particular it seems difficult to create in a hot rock one single fracture large enough to produce a viable system. Therefore it is necessary to support studies that aim at creating a water circulation in a large volume of multiple fractured rock.

Special attention should be devoted to the problems related to the creation of a multipath connection between two boreholes.

The project should essentially concentrate on laboratory experiments and small field experiments with the intention of supporting feasibility studies for this type of energy production.

The environmental impact of a large scale hot dry rock application should be studied.

New concepts should be proposed in order to fit the most favourable geological and thermal situations existing in Europe.

III.6 - Funding

In order to carry out these projects on a cost-sharing basis, a budget of 20 MUAE would be required. The breakdown over the four projects and over the four years of programme duration is estimated as follows:

Project	1979(1/2)	1980	1981	1982	1983(1/2)	Total
A	0.25	0.25	2.0	1.5	0.35	6.6
B	0.25	2.5	2.0	1.0	0.25	6.0
C	0.25	1.25	0.5	0.25	0.15	2.4
D	0.25	1.15	1.5	1.25	0.25	5.0
Total	1.0	8.0	6.0	4.0	1.0	20.0

IV. DETAILED DESCRIPTION

IV.1 - Project A: Integrated geological, geophysical and geochemical investigations in selected areas

Objectives

Obtain more information on certain selected areas with the final aim of determining their geothermal potential.

Actions

a) Collection of data concerning areas of possible geothermal interest.

b) Localisation of geothermal anomalies with combined methods (geological, geochemical, geophysical, etc.) involving surface work and shallow drillings.

c) Testing and intercomparison of known methods by applying them in well known areas.

d) Drilling of exploration boreholes in areas of potential utilisation.

e) Interpretation of data in order to determine the characteristics of reservoirs (geometry, permeability, transmissivity, porosity, water pressure, salinity, etc.).

f) Additional exploration or prospection work which becomes necessary.

g) Setting-up and editing of a geothermal atlas of the European Community.

Funding (in MUAE)

Total	1979	1980	1981	1982	1983
6.6	0.25	2.5	2.0	1.5	0.35

IV.2 - Project B: Subsurface problems of natural hydrothermal resources

Objectives

1) Improvement of drilling and downhole measurement techniques, especially for high temperatures and pressures.
2) Improvement in production, stimulation and reinjection techniques.
3) Definition of reservoir parameters and forecast of the reservoir behaviour.

Actions

1.a) Study of problems related to drilling at high temperatures (cements, muds, packers, coring, temperature resistance of bits, etc.).

b) Development and improvement of logging equipment for high temperature and pressure applications.

2.a) Development of methods and devices for decreasing the flow resistance around the borehole and for connecting it to the reservoir.

b) Study of the stability and destructibility of rock in the presence of hot fluids.

c) Development of methods to control corrosion, erosion and scaling in production and reinjection wells and in the surrounding formations.

d) Studies in order to control phenomena related to reinjection.

3.a) Investigation of reservoir rock and fluid properties.

b) Development of well and reservoir testing equipment (pressure build-up tests, drill stem tests, interference tests, etc.).

c) Development of modelling techniques to forecast reservoir behaviour under depletion and/or reinjection conditions.

Funding (in MUAE)

Total	1979	1980	1981	1982	1983
6	0.25	2.5	2.0	1.0	0.25

IV.3 - Project C: Surface problems related to the use of hydrothermal resources

Objectives

1. Solution of technological problems associated with extracted hydrothermal fluids.
2. Optimal use of hydrothermal resources (heat, minerals, etc.).
3. Control of the environmental impact.
4. Assessment of the economics and of the practical potential of geothermal energy.

Actions

1.a) Studies to control corrosion and scaling in the surface system.

b) Appropriate treatment of circulating fluid (scrubbing, steam-water separation, chemical control)

c) Improvement of heat exchangers, water pumps, etc.

2.a) Study of methods of power generation such as binary cycles and screw expanders.

b) Study of the mineral and gas extraction.

c) Study of the interaction of different heat supplying systems to insure the optimal use of the geothermal resource.

3.a) Investigation of induced seismicity and surface movements (subsidence).

b) Study of the disposal of waste heat and fluids.

4. Monitoring of existing schemes and economic feasibility studies of particular future projects.

Funding (in MUAE)

Total	1979	1980	1981	1982	1983
2.4	0.25	1.25	0.5	0.25	0.15

IV.4 - Project D: Hot dry rocks

Objectives

Investigation of the general feasibility of heat extraction from low permeable rocks.

Actions

a) Initial experiments at shallow depth including continuation of projects already initiated.

b) Studying methods of fracturing large volumes of rocks at great depth.

c) Modelling and experiments on the heat exchange in fractures.

d) Evaluation of natural stress fields at depth and modelling of artificial fracturing of hot dry rocks.

e) Study of the environmental impact of the hot dry rock technology.

Funding (in MUAE)

Total	1979	1980	1981	1982	1983
5.0	0.25	1.25	1.5	1.25	0.25

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ENERGY SYSTEMS ANALYSIS AND STRATEGY STUDIES

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CONTENTS

I. INTRODUCTION

Since the oil price crisis, energy systems analysis has become one of the recognized tools for assessing and defining (mostly medium and long term) strategies in order to cope with energy supply and demand problems. Therefore energy modelling concepts and techniques have been developed at many places, mostly adapted to the individual needs of those organisations (private or public) who intended to use them. By its nature and by the continuous evolution and refinement of the techniques, the development of energy models is a sophisticated and sometimes time consuming work in which, for purposes of practical application, choices must be made between what might constitute the best scientific approach and what can be done with the allocated means, the given time-limit and the available data.

In the framework of the indirect action energy R & D programme approved by the Council on 22nd August 1975, the Community has also launched a programme devoted to the analysis and the development of so-called energy models. Its aim was essentially threefold :

- the development of an instrument enabling the Community and the Commission to better understand the medium and long term energy demand and supply relationships, to anticipate the main energy problems and in that way to be better prepared for their solution. The interrelationships among the different energy issues are too complicated to be assessed by intuition only, therefore a formalised approach had been chosen ;

- to process information relevant for the development of Energy- and Energy R & D policies ;

- to create a modest operational capacity in that field for the Commission.

While this first programme is still under way it can be said that the work undertaken in its framework by about 18 contracting research institutions in the different Member countries and the Commission's own staff, proved already its usefulness as well inside as outside the Commission. It contributed substantially to the development, also in the Member countries, of models based on the same concept and on comparable data presentation, so that their coupling to an EC model is possible as soon as the necessary software is operational and all required data has become available.

In the light of this and taking into account the evolution of the needs of potential model users all over the Community it appears strongly desirable to continue the work under way and to undertake the additional tasks, necessary to have at the Community's disposal a portfolio of modelling tools adapted to its future needs.

This document is presenting, after an overview of the state of progress of the still ongoing first programme, the outline, the rationale and the more detailed work plan for a second Programme on Energy systems analysis and Strategy Studies, as well as an estimation of the budget required for its execution.

II. OUTLINE AND STATE OF PROGRESS OF THE FIRST PROGRAMME

The first indirect action programme carried out in the 1975 - 1979 period is based on a set of objectives which were defined at its beginning by the ACPM, taking account of the general orientations laid down in the programme decision of the Council. In concrete terms, the programme was to assist its users in :

- the development and assessment of alternative energy strategies for the European Communities and their short and medium term effects on the social energy-economy and environmental systems for Europe and the Member states in a World context ; the medium term multinational Community energy model will permit to assess and test in advance a wide range of policy strategies and in that way rationalise further the development of future alternative energy policies. This will be done by optimising the energy fuel mix for a varying energy demand determined under different economic growth assumptions.
- the development and assessment of long-term European R & D policies to back-up alternative energy policies ; the long term Community energy model will contribute to a more rational assessment of a future European R & D policy in the field of energy by essentially assessing the potential of the new energy supply and demand technologies under different optimisation criteria, e.g. price, supply, environment.
- the identification of the interdependent forces and constraints between the different national energy systems of the Member states ;
- the identification of the resources-price-relationships between the EC and the rest of the World.

If the primary objective of the programme is to influence energy planning, such effort should be focussed in particular on the changes the systems may undergo as a function of demand, resources-availability, price, the potential of new technologies and costs at the national, european and world level, its consequences and the possible control by specific policy measures.

This in turn involves the study and evaluation of the following particular aspects :

- the optimisation of the energy-economy system including resources' extraction, energy conversion, distribution and demand
- the development potential of new energy technologies and the likely changes in the social, energy-economy and environmental field resulting from them
- the capital-intensity of new technologies and their influence on the energy-economy systems and cost
- safety and competitiveness of new energy technologies and their impact on the environment (pollution and resources-availability)
- the effect of varying energy-flows in the energy systems on demand supplies and cost
- identification and analysis of the world energy reserves, their availability and price evolution over time
- possibilities of creating a rapid response mechanism to meet specific concerns of policy makers.

The limitations in time and of the budget, the fact that competence and credibility had to be build-up at the same time as interest and cooperativeness had to be generated within all the Member states has led the services of the Commission to make the maximum use of already existing and well established methodologies and to concentrate its efforts to adapt them to their new European application. In addition, a powerful automated European data base had to be developed.

The modelling research programme can be subdivided with regard to the time horizon covered by the models under development into a medium term and a long term activity. Geographically both cover the Member states of the Community, i.e. the Europe of the nine. Whereas in the case of the Commission these models will be run, up-dated and modified by its services, the development and exploitation of world models to study for example the world energy resources-price relationships will be undertaken in a co-operative effort.

Regarding the structure of these models one can distinguish 5 levels for the medium term ($\leq$15 a) and for the long term model ($\leq$4o a).

The medium term model consists of the following sub-systems :

- the multinational energy-data base DAMOCLES
- the simulation model SIMUL for data validation
- the energy economy model EURECA (multinational, dynamic energy-economy model) determining the overall demand
- the energy-demand and interindustry model EXPLOR (mononational, static energy-economy model) determining the energy demand per type of energy sector
- the energy flow model EFOM (multinational, multiphased energy supply-demand, cost optimisation model) optimising the energy supply.

All sub-systems are interlinked through energy-demand and cost. The national sub-systems representations are connected horizontally through EURECA and EFOM by trade, thus leading to a fully integrated multinational coherent model set.

The long term phenomenological energy demand model is of higher aggregation.

It consists of the following elements :

- the multinational energy economy data base
- the scenario generator and cross-impact model SMIC to establish internal consistency
- the long term energy-economy simulation model SLT to translate the scenario variables into the model variables
- the long term energy demand model MEDEE III describing the socio-economic system (urban, industrial, transport)
- the energy flow optimisation model EFOM optimising the energy supplies.

The effectiveness of most of the models developed so far has been tested with the assistance of a large number of European research organisations under contract. An important prerequisite for the successful application of the models consisted in the setting up of an operational unit within DG Research, Science and Education, which coordinated the efforts of the national experts working on the various sub-systems. This coordination proved to be of decisive importance because of the complex modular approach, which had to be done, combining nine national energy sub-models to form the multinational Community model on one hand and the energy-economy and energy demand systems on the other. A modular approach, which takes account of short-, medium- and long-term analytical requirements, proved to be the best solution for future national, multinational or supranational applications.

It makes it also possible to check the basic elements and structural relationships within the various energy sub-systems on the basis of one prototype.

In this way the knowledge of the structural differences in the national energy supply and demand systems could be improved. For example, different demand functions are used now for energy demand estimations in different countries, taking due account of the structural isomorphism of the national sub-modules. This experience could be incorporated before fixing definitely the overall structure of the multinational Community model. The multinational model integrates the national sub-systems and will be operational before the end of the current programme. Its structure makes it also possible to carry out tests jointly with the Member states individually to validate externally the sub-systems of the multinational Community model. The standardized representation of the energy system makes it feasible to quantitatively measure the effects of perturbations from country to country. As soon as the multinational model is available, the results of national case studies will be complemented by multinational analyses and compared with each other. The results of such studies will provide useful information for the development of new european energy and energy R & D strategies.

A simulation model to determine the long term energy requirements is actually being developed to replace the medium term energy economy systems used for the shorter range. The long term demand system can be linked in a similar way with the energy optimisation model for flow optimisation.

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This development work was carried out with the support of a great number of experts from the nine Membersstates and abroad. From the about 18 European research organisations participating directly in the development of the Community modelling instruments about 1o are concerned with the collection of the energy and energy-economy data for the different European states, whereas the remaining have developed jointly with the Commission's services the mathematical models, its software and ensured its proper running. The interactive European network of experts has proven very useful and is now working smooth and extremely efficient. In addition daily internal co-ordination meetings in particular with the Directorate General for Energy and international collaboration through regular exchanges of information with IIASA, IEA, BNL, SRI, and ORNL *) assure that nothing is being overlooked. The great progress of the CEC modelling efforts is largely due to the above organisational approach.

*) International Institute for Applied Systems Analysis, Laxenburg, Austria ;
International Energy Agency, Paris ;
Brookhaven National Laboratory, USA ;
Stanford Research Institute, Menlo Park, USA ;
Oak Ridge National Laboratory, USA .

III. THE SECOND R&D PROGRAMME

III.1 Orientation and Rationale

The models and data banks developed during the first programme are the starting point for many actions of the proposed new programme.

Due to budgetary and time limitations the first programme could not provide answers nor tools covering all interesting aspects of the energy system, which indeed would have been desirable. For that reason the present proposal suggests to complement the systems represented by improving the models methodologically and data-wise where needed during the course of the second research programme. This would ensure the full benefit from the research done during the first programme.

The validation of the structural relationships of the national systems representations and of their numerical data is therefore an important task to be undertaken. Multinational studies with the European model are only worth-while when the national sub-systems have been carefully validated for internal and external consistency. It is therefore strongly recommended to incorporate this action in the new programme.

Since the mastering and efficient handling of such complex, very large-scale models by operational groups is possible only after a lengthy period of familiarisation, the continuity of staff is of great importance in this context. It is therefore proposed that the cooperation between operational groups in the Member states and the operational team of DG XII, begun as part of the implementation of national sub-modules during the first programme, be intensified on a more permanent basis (active network).

Model structures similar to those used for the EC models have been developed and are being used in other parts of the world, as for example at BNL et al., USA and at IIASA in Austria. This led already to a highly fruitful co-operation. Such co-operation could be enhanced where beneficial for the accomplishment of the tasks set out in the new programme.

The first programme deliberately avoided virgin territory - methodologically speaking - to guarantee that the envisaged model system was operational before the first programme expired. For that reason it is proposed to extend the present model concept in a second new programme. This should include for example the development of dynamic systems representations of what were so far static ones. This ensures a more realistic model behaviour for assessing the interactions between the energy system and the demand system and the changes resulting from them over time. Recent methodological developments suggest that this should be no major problem as has been shown for example, through the development of dynamic input-output energy models.

To reduce complexity and save computer time a condensed version of the multinational, timephased energy models should be developed. This would simplify the management of the model system in cases where detailed information is unnecessary. In addition it would enable answering questions of potential users more quickly. Once reduced models were available, it would be possible to apply more sophisticated mathematical techniques to examine with their help interesting questions which could not previously be asked (e.g. the optimum way to apply the policy instruments for a given strategy).

Such structurally simple, aggregated models are also needed for the joint representation of various parts of the World and the World as a whole, in a cooperative effort, as proposed by IIASA and BNL.

A further part of the programme should deal with the problems of communication between model user and model constructor. Since the possible success or failure of the application of mathematical tools strongly depends on this communication, the inclusion of this aspect in the new programme seems important. Available methods and technical aids enabling the user to better understand and interpret the model results or to easier formulate the relevant inputs should be examined or new methods developed. These may include special methods for problem identification, such as the cross-impact techniques. To procure the user direct access to the computer, interactive programmes or conversational computer languages should be used. Although developments in this field are going ahead at great speed, the present state of the art is still not satisfactory.

Since the first programme provided only limited funds for models capable of illustrating the extra-Community environment, this activity should be strenghened in the new programme. For the sake of maximum cost-efficiency it would be advisable to share this task with institutes which are working in a similar direction. One of these would be IIASA, while further intensification of the cooperation with the USA (BNL, SRI, ORNL) would also seem advisable. In such joint activities an attempt should be made to produce world resource models, which would be of particular interest to the Community, with its lack of own resources. Using elements of games' theory, the different world regional energy systems embodied in different socio-economic systems with conflicting objective functions, could be interrelated thus leading to a realistic representation of the World energy systems, elucidating the likely foreseeable international conflicts in the field of energy. Since the rapidly approaching technological problems in the energy sector can be solved best on a world scale, considerable interest should exist to use these models in planning for a common international R & D strategy (IEA).

In conclusion it can be said that the basic thoughts which led to the first energy modelling programme still do exert their effects. The moment is moving closer when a changeover from fossile to non-exhaustible and more capital intensive resources may be necessary. This requires a better understanding of the energy economy consequences. Although the reasons for the worldwide economic recession are not yet fully understood, there can be little doubt that energy plays a central part in it. The increasing interdependence between the energy, economy and ecology is becoming less and less amenable to intuitive understanding. Because of this, alternative energy strategies and energy R & D strategies including the consequences of structural changes in the production system and in private consumption systems caused by the new developments in the energy sector, should be carefully analysed with the aid of models. The critical use of models can improve considerable the necessary analytical capacity and provide the rational basis for the construction of a coherent set of quantitative and optimal resulting scenarios. Models are thus acquiring an increasing importance.

III.2 The New Plan for Action

The first energy modelling programme was allowed for the construction of a coherent set of data bases and models which will be fully operational soon. They have been already of great help in dealing with specific aspects of the new energy and energy R & D strategies developed by the Commission of the EC.

The new work programme can be subdivided into four broad areas of actions ; all are to be developed jointly over the next four years, with greater emphasis on part one in the early years and on part two in the later ones. They are :

1. Improvement and further development of the first Energy Modelling Programme
2. New Energy Systems Representations including recent Methodological Improvements
3. Communications with Potential Users
4. World Energy Modelling.

Chapter IV outlines in greater detail the proposals for the new programme on Energy systems analysis and Strategy studies.

III.3 Funding

It follows from Chapter IV and on the basis of additional information available to the Services of the Commission that the new programme on Energy systems analysis and Strategy Studies for the Commission of the European Communities has the following staff and budgetary implications :

1. Improvement and further development of the first Energy Systems Analysis and Modelling R & D Programme	~81	man years
2. New Energy Systems' Representations including recent Methodological Developments	~ 22	man years
3. Communication with Potential Users	~ 11	man years
4. World Energy Modelling	~ 8	man years
	~ 122	Man Years

As the proposed new programme concentrates essentially on the improvements and further developments of what had been achieved methodologically and data wise during the first programme (~ 66 % of the suggested efforts) it can be considered as an exercise of consolidation. New systems representations and methodological developments (~ 18 %) and the development of means and ways for better communications with potential users (~ 9 %) and World energy modelling (~ 7 %) are constituting necessary complements.

As will be recognised, these four parts are highly interrelated. Although discussed as separate work packages a strong central activity must be maintained in order to guarantee coherence and optimum exploitation. The corollary of this is the further development of a rapid response mechanism to meet the specific energy concerns of the policy makers. For this purpose, a small team of appropriate specialists has to be set-up gradually by the Commission. It should comprise a minimum of four professional officers plus supporting staff.

A proper estimation of the budgetary allocations required for the new action Programme on Energy systems analysis and Strategy studies over the period 1979 - 1983 leads to a total of 7.oo MEUA (i.e. about 2oo.ooo UEA/a per country) including the cost of EC personnel for the aforementioned central team. (The computer costs and the general overheads amount to about 1.oo MEUA for the envisaged programme).

The multi-annual budgetary breakdown reads as follows :

1979	198o	1981	1982	1983
.5oo.ooo	2.5oo.ooo	2.5oo.ooo	1.ooo.ooo	5oo.ooo

The proposed budget of 7.oo MEUA compares well with the national activities in Europe reviewed in the report : "Energy Modelling in the CEC : A Survey of National Programmes" prepared by Professor DRAMAIS for CREST (14th Meeting of 23rd March 1977).

IV. DETAILED DESCRIPTION

IV. 1. Improvement and further development of the first Energy Systems Analysis R&D programme

Work Programme Description

1.1 Maintenance and improvement of data bases and the energy flow model, i.e.

- Updating (present base year is 1974) and centralisation (energy-economy-data are not included yet) of all data bases (centralized use of DAMOCLES) to facilitate maintenance, updating, management and for the sake of internal consistency;
- Automation of the updating procedure and data management using largely existing reference data systems like EUROSTAT and others (e.g. automatic up-dating of I/O tables)
- Development of the necessary software for automatic updating
- Development of more efficient LP optimisation algorithms to reduce the computing costs in particular when using the EC-model in its multinational, time-phased version
- Modularisation of certain parts of the model system to allow for particular runs, thus reducing the needs for costly total-model-runs (e.g. energy demand and supplies by sector)

1.2 Implementation of the national model systems in local research organisation.

To simplify the utilisation of the models, improvements in the system representation and the model structure is required. The implementation, testing and validation should be intensified nationally as well as for the Community. Comparison of results obtained therefrom will enable a better understanding of the undelying systems structures, suggest improvements leading not only to more economic solutions but also to improved model performances and greater credibility of the results obtained. Implementation obviously requires an adaptation of the software to the different computer configurations in use in the Member states.

The projects suggested for this part of the new programme therefore include :

- Implementation and intensive testing of the national model systems by local research organisations
- Adaptation of the software to different computer configurations

(Work Programme Description)

- Case studies and validation on the basis of national policy studies
- Multinational case studies for the Commission of the European Communities
- Improvements in systems representation

1.3 Improvements in the estimation of parameters used in the different models.

Improved technical and economic parameters in the different models for future reference years reduces uncertainties. Technical forecasting and assessment of the energy-producing and consuming systems is done in many parts of the World. A comparative analysis of the characteristic and important elements describing technological systems and their evolution in the future is imperative in particular for the long term studies to reduce the range of uncertainty.

The following research work is therefore suggested :

- New econometric tests, e.g. for the compilation of price elasticities
- Technological forecasting and assessment, e.g. to narrow down the parameters characterising the new technologies in the energy flow models
- Improved methods for the projection of technical coefficients of the I/O tables (in relation with EUROSTAT)

1.4 Complementary developments to existing models.

"Satellite" models can enable better representation of certain subsystems of the energy flow model. Linked to an existing central energy-flow model they can overcome its under-representation of certain aspects of the energy system, e.g. the fuel cycle, the central electricity production, the environment, the energy transport and distribution system etc., without rendering the system unmanageable. In such a way the many requests of better describing certain details of the energy system could be met.

(Work Programme Description)

The following projects should be included into the new programme:

- extension of the environmental part
- extension of certain energy consuming sectors as steel, chemistry, house-heating etc.
- a more refined representation of the nuclear fuel cycle, the central electricity production, the steam power system etc., including energy transport and distribution
- development of a sectoralised technico-economic assessment capacity.

1.5 Further developments of the long term models (MEDEE and SLT)

The long term energy demand model MEDEE and simulation model SLT should be developed further to describe not only the multinational centralised energy system of the Community as for today but to include on the basis of a different systems' structure the description of a regionalised, decentralised energy supply-demand system, as to be expected for some of the new energy production technologies. This would enable to analyse, for example, the implications of matching the energy supplies to needs on a local and decentralised level. Work would include the disaggregation of the supranational SLT simulation model into a multinational model, to better represent the long term national developments and consequences of alternative strategies.

It is also suggested to extend the model geographically to take care of the probable political and geographical enlargement of the Community.

1.6 Dynamic net Energy Analysis

The purpose of this project is to examine the energy resources' consequences of possible energy scenarios for Europe. It is believed that the appropriate methodology for investigating energy policy options from this view point lies in a combination of dynamic economy and energy analysis. Energy analysis gives insight into the likely change in relative prices of energy sources through the assessment of the overall energy requirements for the given demand in energy.

Estimated Man Years (1) 81.5

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7.2 New Energy Systems' Representations including recent Methodological Developments

Although the new programme should essentially be devoted to application and further consolidation of knowledge generated so far it seems wise to introduce recent methodological developments, especially as the first programme was based essentially on existing and proven model concepts to reduce risk, time and costs. Already, a fairly moderate effort can lead to a strong increase of the analytical capacity of the models. Particular benefits can be expected by improving the existing systems representations such, that they possess the capability to analyse the dynamic nature of events and developments in the energy and related fields. The following projects cover this part of the programme.

Work Programme Description

2.1 Dynamization of the disaggregated inter-industry model including new dynamic formulations.

Some of the existing sub-models used are static, e.g. the inter-industry model EXPLOR and the energy model EDM, whereas all the other sub-models of the medium term energy model are dynamic or time-phased. To better identify paths and discontinuities, it is necessary to introduce a more dynamic treatment into all parts of the model. A dynamic modelling system will allow to use the model in a broader strategic context.
This work should include

- the demand by household, the public sector, imports and exports
- the investment by investing sectors
- the input-output coefficients
- employment by sector, and other aspects of EXPLOR and EDM

2.2 Elaboration of "condensed form" models

As it is generally requested to deal with very detailed subject areas (e.g. a specific energy product used in a technical function in an industrial sector of a given country) the family of models adopted by the EC is computationally heavy. The computational requirements will even be further increased with the introduction of year-to-year projections and international linkages. To assure better manageability of the large multinational and time-phased models systems and to enable the use of more refined mathematical techniques, smaller sized models ("models of models") which still should represent well the complex socio-economic energy system of the EC have to be developed out of the existing more comprehensive systems representations. This will offer many advantages, e.g. faster response in strategical use and facilitate the creation of model systems in interplay with other world regions and the like.

In particular it is suggested that some structurally simple aggregated models of energy supply, energy consumption, including price relationships of the more relevant macro-economic variables, the public sector and policy variables, estimated from alternative runs of the existing more detailed dynamic energy models, be developed. Incorporating the principal features of the comprehensive models they should react to changes in the world environment (e.g. changes in petroleum prices) or to specific national policies (e.g. nuclear investment policies).

2.3 Application of new methods of programming, e.g.: optimal control, dynamic programming, decentralized optimal control and game theoretic approaches to study the possible future paths and the alternatives faced by the economic agents (mainly EC and national Governments).

The relation of national energy policies with EC common policies is a subject that should be treated in the EC energy model system. This subject could be dealt with using condensed forms of the full models and investigating alternative objective functions for the different countries and the EC. For the purpose of practical application the optimal control method (dynamic modelling) is suggested. Such model should be capable to determine the optimum method of applying the policy instruments to achieve the desirable objectives, given the desirable values for the main energy economy policy over the next 5 - lo years. In case the global optimum does not correspond to the specific optimum of the individual countries one could consider the EC countries playing a sort of co-operative game. Using goal-interval programming, the problem that is, given an EEC central optimum each state will try at the same time to maximise its own welfare function and minimise the distance to the central objective, can be solved.

2.4 Sequential modelling

Sequential L.P. models have the computational advantage that they can be solved by breaking the total problem down into a number of single interval problems, thus allowing large problems to be solved. In addition the decision patterns of this modelling approach are different from the time phased L.P. models used so far. In practical terms it turns out that the answers provided by the sequential approach are more conservative. This approach could be a useful alternative for mastering complex, multi-national systems representations.

Estimated Man Years (2)

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IV.3 Communication with Potential Users

It is essential for the success of any energy systems analysis programme that a good understanding is established between the model builders (and their limitations in terms of data-theoretical understanding) and the model users and their requirements. A "translation" mechanism is required working in both directions : interpreting the requirements of the user and translating the results in terms understandable by the user. This double function of translation is to be handled carefully both at the Community level and for the national applications after the implementation of the models on the national level. Some general projects are suggested to facilitate this translation and information transfer process :

Work Programme Description

3.1 Identification and analysis of problems of interest to the user necessary for designing assumption scenarios (inputs) and resulting scenarios (outputs) of potential interest.

Methodologies to facilitate the process of identification in a systematic formalized manner include DELPHI, cross-impact techniques, interpretative structural modelling, as well as new methods of scenario generation. Some of these methods as well as others may be used together with additonal expert judgement on non-quantifiable factors to establish resulting scenarios (outputs) for answering the users questions. This area is in a rapid process of development and new methodologies will become available within the next years.

3.2 In advance computation of alternative trends, events, and policies related both to the socio-economic and the energy system and measurement of their impacts.

The advance computation of alternative trends, events, and policies and their impact evaluation should be made available to potential users as an in advance orientation of future possibilities (e.g. in terms of employment, balance of payments, energy-investment requirements, petroleum demand etc. ...). This kind of analysis and its outcome could be helpful to develop consistent and feasibel concepts for a variety of problems relative to energy.

(Work Programme Description)

3.3 An interactive system written in conversational language for direct access of inputs and outputs provided with graphic displays and hard copy capability and other appropriate terminals.

There is always the problem of engaging persons who are not modellers but rather potential users in dealing with models and their results. The Commission is within a process of establishing an energy model system which is outstanding because of its extent regarding the number of countries. However, so far the EC-models do not, just as almost any other model, present themselves and their results in a form which is easily understood by the user. It is therefore suggested that an interactive conversational information retrieval system will be developed within the context of the new programme to facilitate the mutual understanding.

Estimated Man Years (3) 11

IV. 4. World Energy Modelling

During the first Energy R & D programme the systems analysis and modelling effort of the Commission has been largely inward-looking in respect to the application of the methodologies which were developed. Considering the future programme it becomes immediately apparent that the horizon must be expanded in order to establish how the various internal proposals will impact upon the world and vice versa. This has the corollary of ascertaining which of their internal scenarios are in fact consistent with likely world reactions and with the aspirations of others, such as the developing countries. Europe being a highly industrialised, resource poor region the purpose of this action is essentially to determine the specificities of Europe in relation to likely world developments (energy-demand, -supply, -price relationships) over time and to provide better data for each imported energy source and the new technologies up to the year 2o3o, as inputs to the European analyses.

It is clear that the Commission's services are unable to review and forecast the changing situation on a world regional level without substantial external support. The following actions are therefore suggested for the new energy systems analysis research programme :

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Work Programme Description

4.1 Development of a "multi-regional" World model in a cooperative effort

Using the condensed models of the European Community and similar models for the other world regions and game theory for interrelating the different regional energy systems embodied in different socio-economic systems with conflicting objective functions, it should be not too difficult to develop a multi-regional World model. Political contacts and technical exchange being already in progress between the Commission, BNL, ORNL, IIASA and IEA and the necessity of any World analysis to include the widest range of international assessment possible, makes that operation appear a very desirable and a natural extension of the current collaboration between the CEC, BNL and IIASA.

4.2 Further participation in the multiclient World energy modelling activities of SRI, MIT*), QMC**) and others.

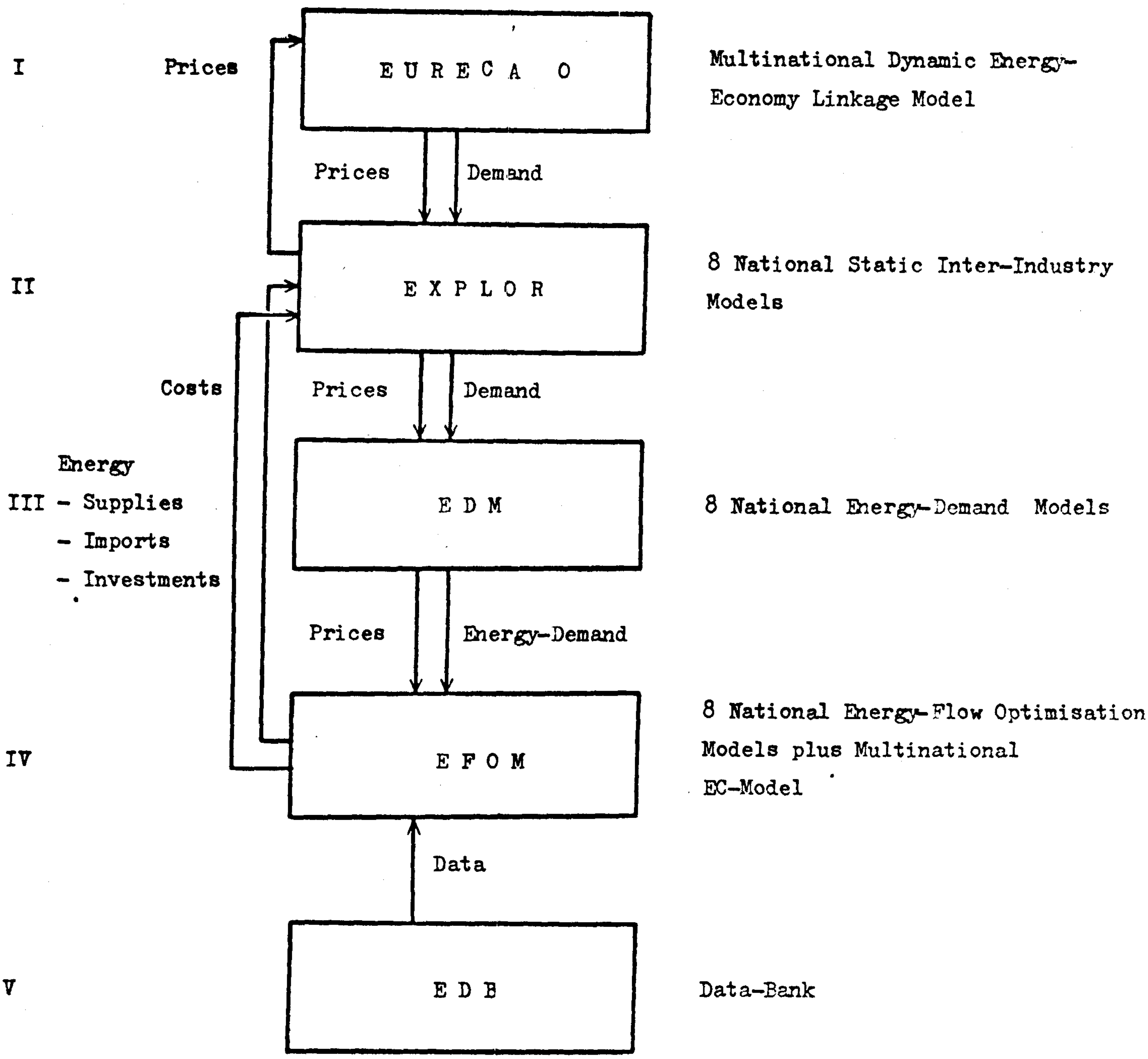
During the first energy modelling programme only a limited number of case studies could be performed using the World energy model of Professor DEAM (QMC-London) and through participation in a multi-client study of SRI. It is therefore suggested that the current participation be extended to include special case studies to test the impacts of World political, social and economic developments on Western Europe and the European Community. The main advantage of using centrally generated World models is undoubtedly internal consistency in structure and data.

Estimated Man Years (4) 8

*) Massachusetts Institute of Technology, USA ;

**) Queen Mary College, London.

Diagrammatic representation of the EC Medium Term Energy Model



Diagrammatic representation of the EC Long Term Energy Model