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A/CONF.100/IGO/3
13 August 1981

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RENEWABLE ENERGY IN THE INTERNATIONAL ENERGY AGENCY - PREPARING TODAY FOR THE NEEDS OF TOMORROW

Secretariat of the International Energy Agency **

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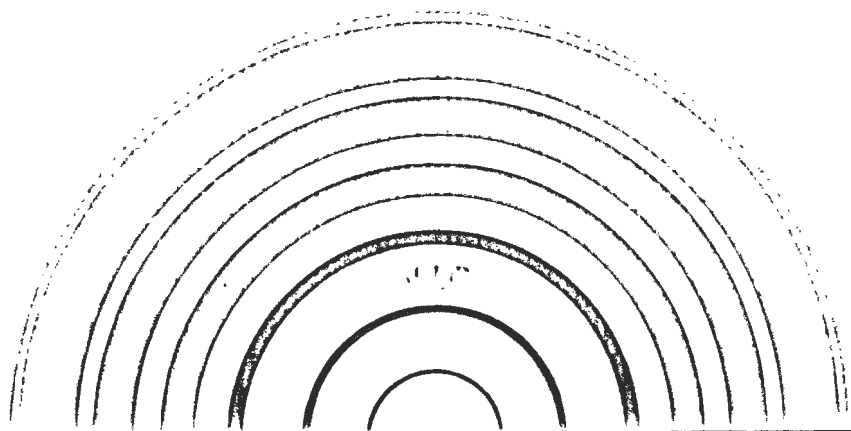
NA/81-0158

INTERNATIONAL ENERGY AGENCY



RENEWABLE ENERGY IN THE IEA

preparing today for the needs of tomorrow

OCDE
OECD
PARIS 1981

CORRIGENDUM

ON PAGE 2, LINE 4, FOR "TWENTY", READ "TWENTY ONE".

ON LINE 17 OF THE SAME PAGE, AFTER "NORWAY", INSERT "PORTUGAL".

INTERNATIONAL ENERGY AGENCY

RENEWABLE ENERGY IN THE IEA

preparing today for the needs of tomorrow

Report to the United Nations Conference
on new and renewable sources of Energy
NAIROBI, AUGUST 1981

INTERNATIONAL ENERGY AGENCY
2, RUE ANDRÉ PASCAL 75775 PARIS CEDEX 16 , FRANCE

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Program.

It carries out a comprehensive programme of energy co-operation among twenty* of the OECD's twenty-four Member countries. The basic aims of IEA are:

i) co-operation among IEA Participating Countries to reduce excessive dependence on oil through energy conservation, development of alternative energy sources and energy research and development;

ii) an information system on the international oil market as well as consultation with oil companies;

iii) co-operation with oil producing and other oil consuming countries with a view to developing a stable international energy trade as well as the rational management and use of world energy resources in the interest of all countries;

iv) a plan to prepare Participating Countries against the risk of a major disruption of oil supplies and to share available oil in the event of an emergency.

* IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

The Organisation for Economic Co-operation and Development (OECD) was set up under a Convention signed in Paris on 14th December 1960, which provides that the OECD shall promote policies designed:

— to achieve the highest sustainable economic growth and employment and rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;

— to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development;

— to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The Members of OECD are Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

TABLE OF CONTENTS

COLLABORATIVE RD & D PROJECTS

INTRODUCTION

This paper describes new and renewable energy programs and projects taking place under the aegis of the International Energy Agency (IEA), a twenty-one nation organization within the framework of the Organization for Economic Cooperation and Development (OECD).

The work of the IEA most relevant to UNCNRSE is its energy research, development and demonstration (RD & D) activities. The IEA is involved in solar, biomass, wind, geothermal, enhanced oil recovery, coal, nuclear and conservation activities. This paper examines the IEA work being done in each of these areas, particularly its relevance for non-member countries. It further discusses the possibilities for collaborative RD & D activities in new and renewable energy with non-member countries and in particular with developing countries.

The IEA RD & D Program

Member countries represent a major portion of the world's technological capability in energy RD & D. Through the IEA, member countries have established collaboration research projects in most of the important energy technology groups:

— Coal
— Enhanced Oil Recovery
— Geothermal
— Solar
— Biomass
— Ocean
— Wind
— Fusion
— Hydrogen

Once two or more countries agree to collaborate in energy RD & D, Implementing Agreements are negotiated. An Executive Committee, comprised of representatives of participating countries, is appointed to supervise each project. In practice, the Executive Committee delegates day-to-day management of the project to one lead participant who acts on behalf of the other participating countries.

The activities depend on active involvement by all participants, whether by contributing manpower, services or materials, or by supporting the project financially. As there is no central IEA funding for projects, the project participants decide among themselves how to pay for the project. As the project summaries in this report show, the financial contribution of each participant varies from $4000 in the biomass information project to $2.5 million for one of the geothermal projects. In some projects, there is no direct financial contribution, rather participating countries provide staff resources.

Relevance of IEA RD & D to non-members

The IEA has often expressed its interest and willingness to examine with developing countries potential areas of cooperation in energy research and development.

Within the context of the UNCNRSE, it is probable that non-members of the IEA most interested in the RD & D activities of the IEA would be developing countries, including newly industrializing countries. The range of IEA RD & D activities is such that most developing countries, whether principally agrarian or newly industrializing, could benefit from involvement.

Collaborative activities of interest to non-members are likely to be of three types:

(i) Technical information exchange.
(ii) Task-sharing, in which each participant conducts a part of the work and all resulting information is shared.
(iii) Construction and operation of a specific RD & D installation jointly funded by two or more countries.

The IEA Governing Board, in April 1977, approved the following guidelines for the participation of developing countries in the RD & D work of the IEA:

(1) developing countries which have or plan to have an RD & D program on a particular energy source can participate in the technical discussion of the appropriate IEA RD & D Working Party;

(2) developing countries can participate in IEA information exchange projects when their contribution, in whatever form, is substantial, and in task sharing projects when they have programs underway, or plan to finance such programs, which are reasonably comparable to those of the IEA Country Participants;

(3) developing countries may participate in IEA jointly-funded projects on bases reasonably equivalent to that of IEA country Participants;

The IEA welcomes suggestions from developing countries on RD & D and information exchange projects of particular relevance to them. In deciding on program priorities for cooperation with non-members, the IEA is prepared to take account of the technologies needed by developing countries.

The following pages describe various new and renewable projects which the IEA is currently doing or has completed recently.

COLLABORATIVE RD & D PROJECTS

BIOMASS CONVERSION

Background

Biomass ranks among nature's renewable and potentially plentiful energy resources. Biomass includes all types of organic matter but interest is focused generally on fast-growing trees, energy-rich crops, certain water weeds and algae, waste products from agriculture and forestry and petroleum bearing plants.

To a certain extent, the great variety of plant life is reflected in the variety of known thermal, biological and chemical conversion processes. The wide range of end products which can be made available enhances the potential usefulness of biomass as a source of energy. There is, however, a need for continued research and development into production and conversion processes and land use problems.

IEA Activities

Two programs of co-operative activity are taking place in the area of energy from biomass. The objective of the Technical Information Service is to provide the participants with a regular source of information on scientific and technical data on all aspects of biomass energy. The forestry energy program was established with the objective of developing a program of co-operation and co-ordination in the planning and execution of national programs as well as jointly executed projects whenever possible and suitable.

Technical Information Service

The objective of this program is to provide the participants with a regular source of information on scientific and technical data, including production, harvesting, collection, processing, transportation and conversion techniques.

The information is presented in the form of:

— abstract bulletins

— literature reviews and searches on selected topics

— referral service for documentation, data and research activities

— co-ordination with other information services.

Preparation of the bi-monthly current awareness bulletins and retrospective searches are major activities of the information service. The bulletins, at present published in hard copy form, contain abstracts on various aspects of biomass energy under the following headings:

— Animal Wastes

— Crop Residues

— Domestic and Urban Wastes

— Forestry Products

— General and Review Topics.

The aim of the service is to provide comprehensive world-wide coverage of items relating to biomass energy. Scientific and technical journals, reports and conference proceedings are abstracted to provide the source material. In addition, designated representatives within member countries collect and supply to the service information available within their country which is not readily accessible through the normal publishing channels.

Retrospective searches on the following topics have been carried out:

— Short Rotation Forestry

— Annual Status Review

— National Inventory of Biomass Resource: Ireland

— Harvesting of Biomass

— Combustion and Pyrolysis of Wood and Wood Wastes

— Short Rotation Forestry Update

— Biochemical Production of Alcohol Fuels

— Harvesting Forestry Residues

— Thermochemical Production of Alcohol Fuels

— Biomass Energy Systems Analysis

— Wood and Wood Residues as a Source of Chemicals

— Wood and Wood Waste Burning Equipment

The remaining two searches in preparation are:

— Inventory of National and International Research Programs

— Environmental Effects of Biomass systems

A thesaurus of biomass terms was completed and distributed to members during 1979. This thesaurus was developed further in 1980 and made compatible with the energy information data base subject thesaurus maintained by the United States Department of Energy. The current awareness bulletins are now available in hard copy form and on magnetic tape. The cataloguing scheme to be used has been adopted from the INIS scheme and utilises the simplest data field structure. The thesaurus of biomass terms has been used to assign keywords to each abstract and for the subject and author indices.

The feasibility and implications of developing the present biomass current awareness service into a full-scale mechanised data base,

capable of on-line interrogation and retrieval, has been investigated. At the same time, associated marketing possibilities were examined. A decision on the preparation of an on-line data base will be taken in 1981.

Duration:	1978 - 1981
Participating Countries:	Austria, Belgium, Canada, Germany, Ireland, Italy, Japan, New Zealand, Sweden, Switzerland, United Kingdom, United States and the Commission of the European Communities
Operating Agent:	National Board for Science and Technology Shelbourne House Shelbourne Road Dublin 4, Ireland
Annual Cost:	$55,000 (Equal shares) $200,000 (overall cost)

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Forestry Energy

Forestry energy encompasses the use of short-rotation forestry biomass and forest residues to produce clean fuels, petrochemical substitutes and other energy-intensive products. During 1980 there has been an expansion, from nineteen to twenty-five, in the number of forestry activities underway within the four planning groups.

In the area of systems analysis, work on identification of evaluation criteria for biomass systems analysis and on growth and production models was completed in 1980. Work is continuing on biomass energy systems identification and on an inventory of relevant systems analysis models. A biomass systems analysis workshop was held in October

1980. New systems analysis activities initiated in 1980 include studies of short rotation forestry plantations; forestry energy growth models; small scale district heating systems studies and work on the integration of pyrolysis and saw milling systems.

A number of status reports have been published in relation to the work underway on growth and production of forestry energy. Final reports on propagation and weed control are being published. Reports on species inventory, yield factors, factors influencing coppicing, water use efficiency, hybridization requirements in Salix and biomass plantations on forest sites will be available after completion of the work in mid-1981.

Work on harvesting, on-site processing and transportation and studies on wood preservation have been completed and were discussed at a biomass workshop in September 1980. Two new activities on harvesting systems for short rotation forestry and for small trees and logging residues are underway.

During 1979, a study on environmental aspects of wood firing was concluded and a wood firing handbook is in preparation. A new activity to plan, design, construct, and test a biomass liquefaction facility commenced at the end of 1980.

Duration:	1979-1981
Participating Countries:	Austria, Belgium, Canada, Denmark, Ireland, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States
Operating Agent:	National Swedish Board for Energy Source Development Box 1103 S-16312 Spanga, Sweden
Annual Cost:	$50,000 (Equal shares) plus 1-2 man years per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Cloned Salix short rotation forestry project in Sweden.

SOLAR ENERGY

Background

The importance of solar energy to the energy supply of the future is increasingly recognised. The broad base of solar energy technology enables it to have some applicability for many end uses of energy both in industrial and developing countries. Widespread research is being carried out into solar heating and cooling and the generation of electricity by thermal and photovoltaic means. In view of the advanced state of development of much of the technology, increasing attention is being paid to the development of standard testing and measurement procedures and manufacturing codes. In addition, many countries have set tentative targets for the contribution to be made by solar energy and are establishing demonstration programs in order to make the capability of solar energy more widely known, and, in many cases, providing incentives for its use.

IEA Activities

Two major IEA collaborative programs are taking place in the field of solar thermal RD & D. In the solar heating and cooling program, seven projects in different areas are being undertaken. In the small solar power systems project, the use of solar energy for the generation of electricity is being developed through the construction of two solar power plants.

Investigation of the Performance of Solar Heating and Cooling Systems

The overall objective of this task-sharing program is to increase the cost effectiveness of solar heating, cooling and hot water supply systems.

This is being achieved through international co-operation in the prediction, measurement and reporting of system thermal performance and the optimisation of system economics.

During 1979 reports on three topics were finalised. A report on the comparison of simulation techniques and the modelling of solar heating and cooling systems has enabled the status of these techniques to be assessed. It is now possible for research workers to check a simulation program against the eight programs which are described in the report.

A report on System Thermal Measurement Procedures provides standardized nomenclature and procedures to serve as a guide to monitor and evaluate research or demonstration solar systems components and buildings. Performance factors, data requirements, measurement parameters and methods of data analysis are described for typical solar energy systems.

A format for reporting the thermal performance, durability and cost of solar heating and cooling systems was distributed in February 1980. The objectives of the format are to ensure that sufficient information is provided in reports to enable the reader to make his own assessment of the thermal performance of a solar system. It is not a technical report as such, but a guide to writing complete technical reports. The report highlights the necessity of reporting the results from experimental and analytical studies in comparable formats, thus facilitating the increasingly important work on the validation and comparison of test results.

Work has continued on the study of optimisation procedures. Specific results on optimal system designs for each country are not being distributed, primarily because of difficulty in agreeing upon economic parameters and optimisation criteria. Sensitivity of the life cycle economic analysis to parameter variations (such as fuel costs) has been investigated and results have been documented in a report which will be finalised by mid-1981.

For the validation activity, computer simulations have been compared with actual system performance. In carrying out the simulation of a large solar heating and cooling system and comparison to experimental data for the system, most programs agreed to within 2 per cent of the

measured data. This level of accuracy is comparable to the expected accuracy for the measured data.

The validation work is continuing with studies involving four domestic hot water systems. To support these studies, a detailed validation format has been prepared, condensed into a general document appropriate for future validation studies.

A new program on solar assisted low energy dwellings (SALED) commenced late in 1979. The work is focusing on the practical aspects of the design and constructions of SALEDs. A workshop for builders and architects was held in February 1981. A survey of existing SALEDs has been completed and a dwelling will be selected to provide data for the validation of simulation methods.

Duration:	1977-1983
Participating Countries:	Belgium, Denmark, Germany, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States and the Commission of the European Communities
Operating Agent:	Thermal Insulation Laboratory Building 118 Technical University of Denmark DK-2800, Lyngby, Denmark
Annual Effort:	1/2 to 2 man years per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Co-ordination of RD & D on Solar Heating and Cooling Components

The objective of this project has been to increase the effectiveness of the RD & D activities of the participating countries in the development

of cost effective components for solar heating, cooling and hot water supply systems. Participants have completed summaries of government funded component RD & D and a 'Survey of Solar Energy RD & D Projects for Solar Heating and Cooling Components' is being published. The matrix coding system developed for this activity was designed to provide an overview of the world research community's perception of where the major emphasis in research is needed to make solar energy a viable energy source. Results from this survey and review of editorial plans will be available by mid-1981.

Duration:	1977-1984
Participating Countries:	Austria, Belgium, Denmark, Germany, Greece, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United States
Operating Agent:	Agency for Industrial Science and Technology Sunshine Project Headquarters AIST-MITI 1-3-1 Kasumigaseki Chiyoda-ku, Tokyo, Japan
Annual Effort:	1/2 man year per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Performance Testing of Solar Collectors

The solar collector is the key component in an active solar energy system. Because of the wide variety of different collector designs with a broad range of qualitative differences, it is important that, as a basis for selection, the thermal and economic performance of collectors can be determined. The objective of this task-sharing program is the development and utilisation, on an international level, of standard test procedures which will enable the thermal performance, reliability and

durability of solar collectors to be ascertained. The testing of the thermal performance of collectors plays a central role in this task, since such tests provide the necessary data for system design and the prediction of system performance. The tests also form the basis for reliability and durability trials.

Work on the development of standard test procedures to determine the thermal performance of flat plate collectors concluded in 1979. In the report "Results and Analysis of the IEA Round-Robin Testing" the sixteen participating laboratories recommended both procedures examined (ASHRAE-USA and BSE-Germany). In this method of testing, each collector was examined by each of the participants. The two recommended test procedures are now being applied by the participants to two evacuated tube collectors of Japanese and United States manufacture. The objective of this second series of tests is to evaluate the modifications which would enable the test standards to be applied at higher temperatures.

Work is continuing, however, on flat plate collectors. A further "round robin" program to compare indoor heat loss measurements using a cover device on the two flat plate test collectors used above is under way.

Methodological uncertainties have hampered the development of reliability and durability test procedures. Through a new approach of surveying collector failures during operation, accelerated aging of collectors and the application of existing durability cases, the participants will recommend the development of an IEA procedure for testing the integrity and reliability of collectors.

A report on a survey of solar simulator test facilities and initial results of IEA tests using solar simulators has been completed. Participants felt that a careful study of the functional characteristics of the simulators should be accomplished before an empirical investigation of certain collector parameters is undertaken. Although a number of participants have decided to use a simulator to allow year round testing, its role in collector testing has not yet been fully evaluated. Further work is being carried out. As a result of an *ad hoc* comparison of pyranometers, a program to conduct a comparative, long term

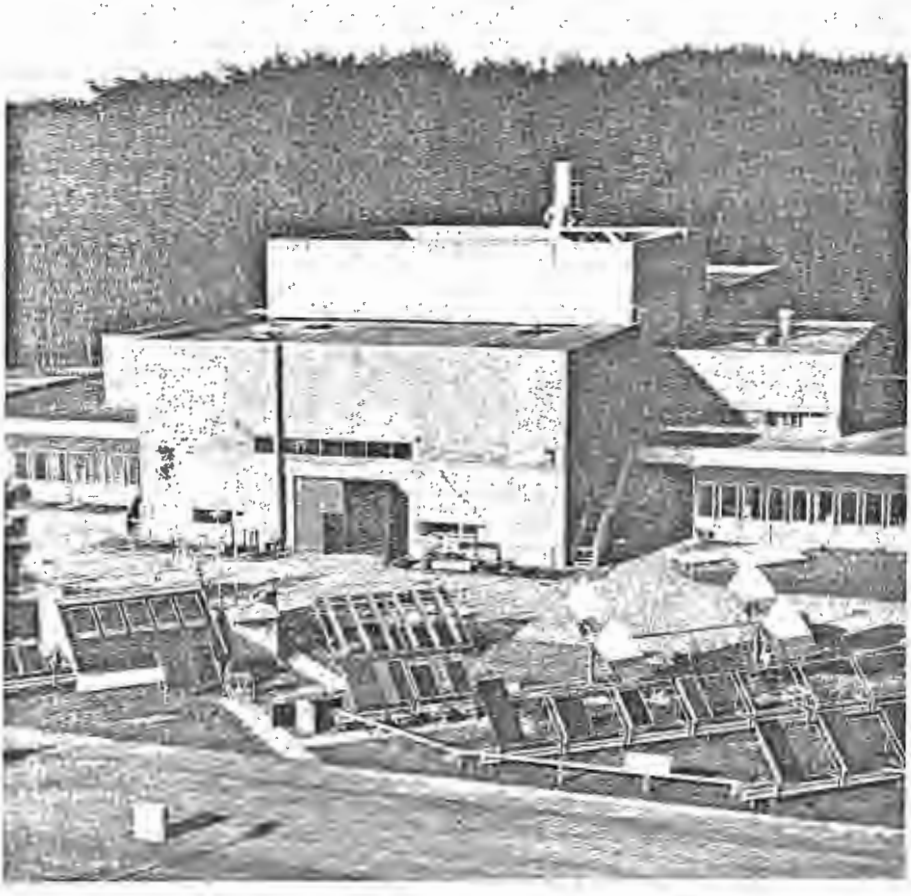
performance monitoring of different pyranometer types is being undertaken. The objective of this program is to ascertain the reasons behind the discrepancies in pyranometer readings.

Duration:	1977-1982
Participating Countries:	Austria, Belgium, Canada, Denmark, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, Switzerland, United Kingdom, United States and the Commission of the European Communities
Operating Agent:	Kernforschungsanlage Jülich GmbH Postfach 1913 D-5170 Jülich, Germany
Annual Effort:	1/2 to 3 man years per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Development of an Insolation Handbook and Instrumentation Package

The objective of this project was to obtain improved basic information for the design and operation of solar heating and cooling systems through a better understanding of the required insolation (i.e. solar radiation), related weather data and through improved techniques for the measurement and evaluation of such data. A meteorological measurements handbook has been complied and design and performance specifications developed for an instrumentation package for measuring insolation and other meteorological data. Comparison tests of two portable instrumentation packages were finalised in 1979. The two devices operated according to specifications during bright sunshine but not during changing or overcast weather conditions. This may have



Solar collector test field at KFA, Jülich

been due to difficulties in aiming accurately the instruments in the absence of bright sunshine. The final reports were published in 1980. This project increased the awareness of meteorologists to the particular measurement requirements of solar energy.

Duration:	1977-1979
Participating Countries:	Belgium, Canada, Germany, Italy, Netherlands, Spain, Switzerland, United Kingdom, United States and the Commission of the European Communities
Operating Agent:	Office of Technical Cooperation United States Department of Energy Washington, D.C. 20585
Annual Effort:	1/2 to 1 man year per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Use of Existing Meteorological Information

This program on meteorological aspects of solar energy, which is closely related to the previous project, concentrates on the use of already measured solar radiation data rather than on its measurement. The objectives are to determine the quantitative relationship between measurements of solar radiation and other relevant meteorological parameters. In addition, an internationally uniform system of presentation of solar radiation data is being developed which will facilitate the undertaking of the calculations necessary for utilising solar energy. This project should improve the availability of existing solar radiation and relevant meteorological data, provide uniform methods for data presentation, improve methods of estimating solar radiation and enhance performance of existing meteorological stations.

During 1980 the Data Source Catalogue was finalised. It contains an evaluated list of current measurements of solar radiation and relevant working data in participating countries. The instruments used to gather

data are described and the sources of error identified and evaluated. The catalogue was published in 1981.

Methods of estimating solar radiation are being validated using data presented in a common format from the participating countries. Following completion of the validation in April 1980, a handbook containing the compilation of the results and a description of the methods has been prepared. To improve the measurement of solar radiation according to the needs of system developers and users, participants have submitted inventories of users' requirements for solar and meteorological data, including its accuracy. A report, which makes recommendations concerning meteorological observation stations, was published in 1981. In order to assist meteorological stations to present the data they collect to users and designers of solar energy systems in a uniform way, an internationally uniform format is being developed based on information supplied by the participants. The standard format, which will be published in mid-1981, will facilitate the planning and design of buildings and equipment using solar energy.

Duration:	1977-1981
Participating Countries:	Austria, Belgium, Canada, Denmark, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States and the Commission of the European Communities
Operating Agent:	Swedish Meteorological and Hydrological Institute Box 923 Fack S-60101 Norrköping, Sweden
Annual Effort:	1 to 2 man years per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Performance of Systems Using Evacuated Collectors

The use of evacuated collectors eliminates the heat loss through

convection and conduction of the air around the surface of the collector. This feature enables much higher temperatures to be achieved than is possible with simple flat plate collectors. This new program has the objective of furthering the understanding of the performance of evacuated collectors in solar heating, cooling and hot water systems, and to study, document and compare the performance and characteristics of such collectors in different systems and climates.

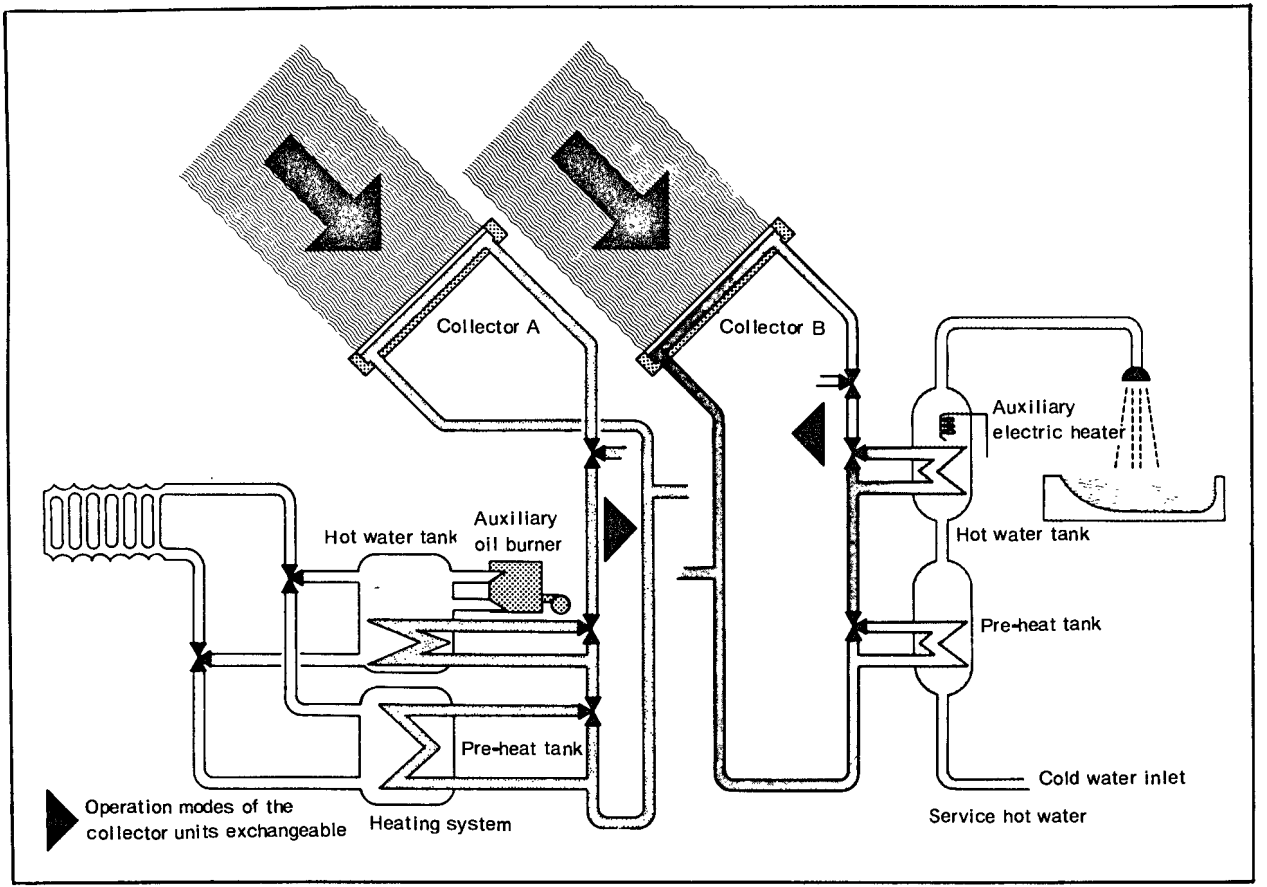
During 1980, five operational well instrumented solar dwellings were used in the program. The remaining three installations will be integrated into the common reporting system in 1981. The installations include single and multi family heating and cooling and hot water production, district heating and industrial process heat projects. The reporting format for the system performance tests which is being prepared is based on the one developed in the work on the performance of solar heating and cooling systems (see above). The emphasis in this program is on the testing of the system under real load conditions as opposed to collector testing and simulation.

Duration:	1979-1982
Participating Countries:	Canada, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom, United States
Operating Agent:	Office of Technical Cooperation United States Department of Energy Washington D.C. 20585
Annual Effort:	2 to 5 man years per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Central Solar Heating Plants with Seasonal Storage

The objectives of the project are to determine the technical feasibility and cost effectiveness of large scale seasonal storage solar energy



Solar House Freiberg, Germany; flowsheet of hot water and central heating system.

systems for the heating of buildings; to evaluate the merits of alternative large scale system designs for collecting, storing and using solar energy, and to prepare detailed system designs for specific site parameters. There is close collaboration in this work with the IEA group involved in energy conservation in buildings.

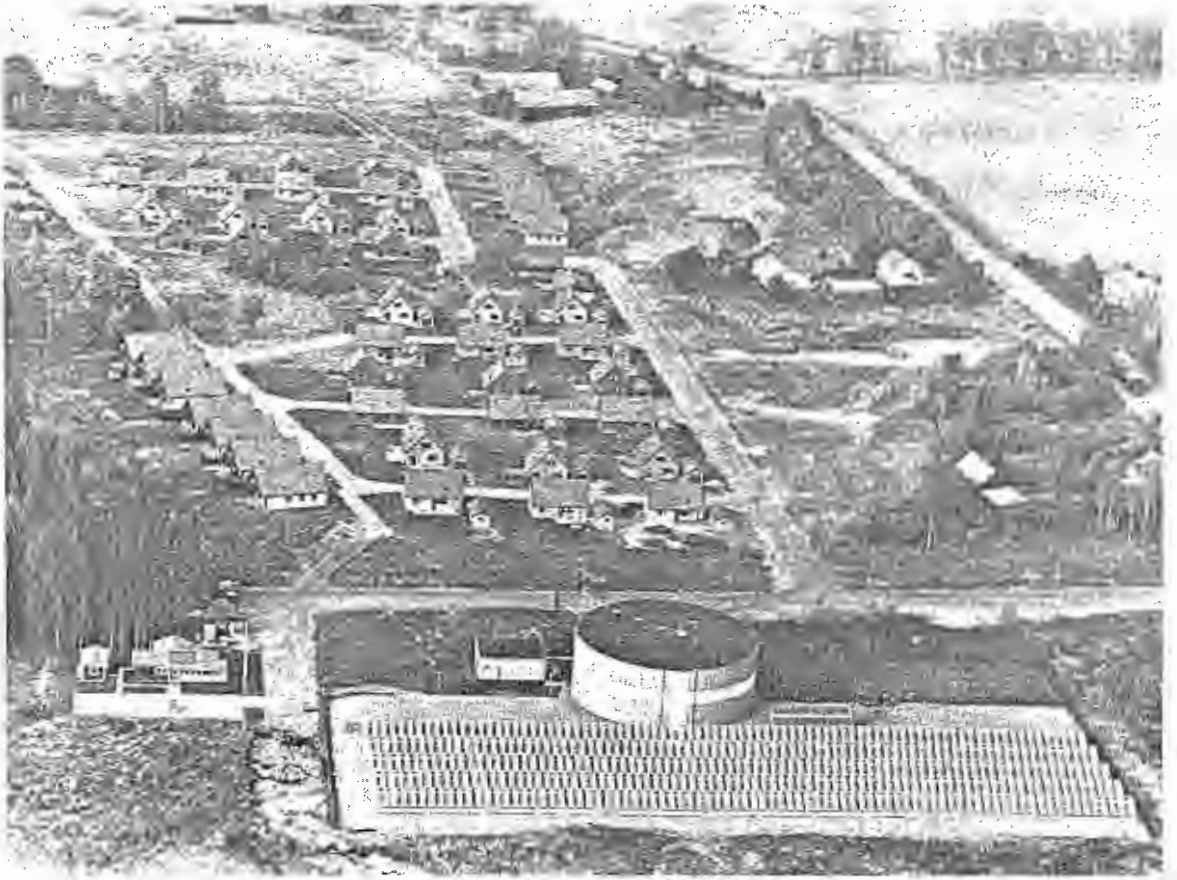
Two phases are envisaged for this project. The first involves literature surveys, the development of system and subsystem simulation techniques, computer codes and data to enable the optimisation of a design, the selection of components, storage technique and method of energy distribution for an optimised system and its design. Following the completion of Phase 1, the development of detailed system designs will be undertaken.

Duration:	1980-1984
Participating Countries:	Canada, Germany, Netherlands, Sweden, Switzerland, United Kingdom, United-States
Operating Agent:	Swedish Council for Building Research St. Göransgaten 66 S-11233 Stockholm, Sweden
Annual Effort:	1/2 to 1 1/2 man years in phase 1 per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Small Solar Power Plant Demonstrations

Although most of the components and technology used in a solar thermal power station are well developed, the specific systems application of solar energy has its own problems. Because of the low concentration of solar energy in any one place, very large collecting devices are required which must have high performance, a long life and low cost before they can be utilised. Demonstration and test plants are therefore necessary even if mature technology is being applied.



Solar Heating plant, Ingelstad, Vaxjo, Sweden, showing solar collectors, storage tank and single family homes connected to the plant.

By constructing two power plants of dissimilar technologies on the same site, direct comparisons can be made under identical realistic operational conditions. Participants in this project are funding the construction and operation of a solar "farm" project and a solar "tower". Both of the 500 kW plants will, when completed, be operated while feeding into the electricity grid. This makes this IEA project one of the most advanced of its type in the world.

The distributed collector system (solar farm) collects and concentrates solar irradiation in a decentralised way by utilising parabolic trough type reflectors of short focal length working in series. Two different collector fields of approximately equal size are being utilised. One field comprises 10 rows of 60 collectors, the other consists of 14 rows of 6 collector modules. A third field is to be added at a later stage. Pipework located in the focal lines of the troughs becomes heated raising the temperature of the working medium (thermal oil) to 295°C. The heat contained in the oil is used in three heat transfer loops to drive a steam turbine which generates electricity in the normal way. The overall efficiency of the plant (insolation/net electricity) is expected to be about 10 per cent.

Designed for a lifetime of ten years, the plant will, together with thermal storage, deliver a nominal 500 kWe for about 2000 hours a year.

The central receiver system (power tower) has an energy receiver located on a tower 43 meters above the ground in the focal point of a mirror field consisting of about 100 individual heliostats which track the sun both in azimuth and elevation. In this way, the solar irradiation is concentrated by a factor of 450. The main feature of this solar tower is the application of liquid sodium, heated to 530°C, as a heat transfer and storage medium. Two different receivers will be compared during the project. This plant, which is representative of plants of up to 100 MW, will deliver 500 kWe for 2500 hours a year at an overall efficiency of about 14 per cent.

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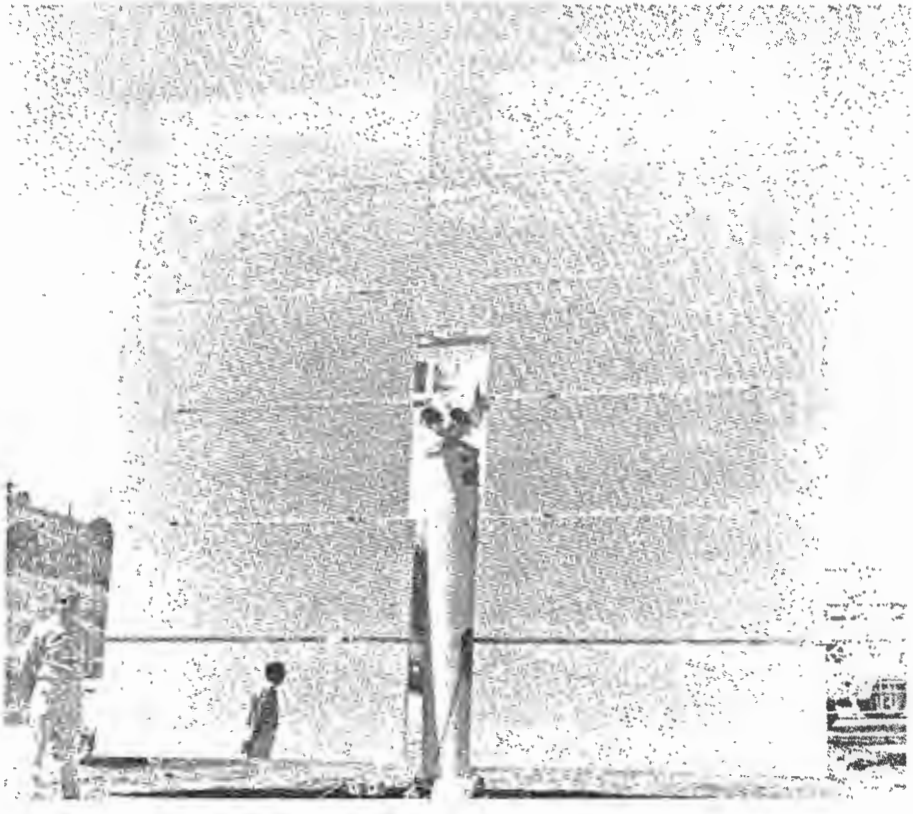
Construction of the two power plants is proceeding according to schedule and will be completed in July 1981, with test operation commencing shortly after. The site will also accommodate a Spanish national solar energy project which will enable sharing of services.

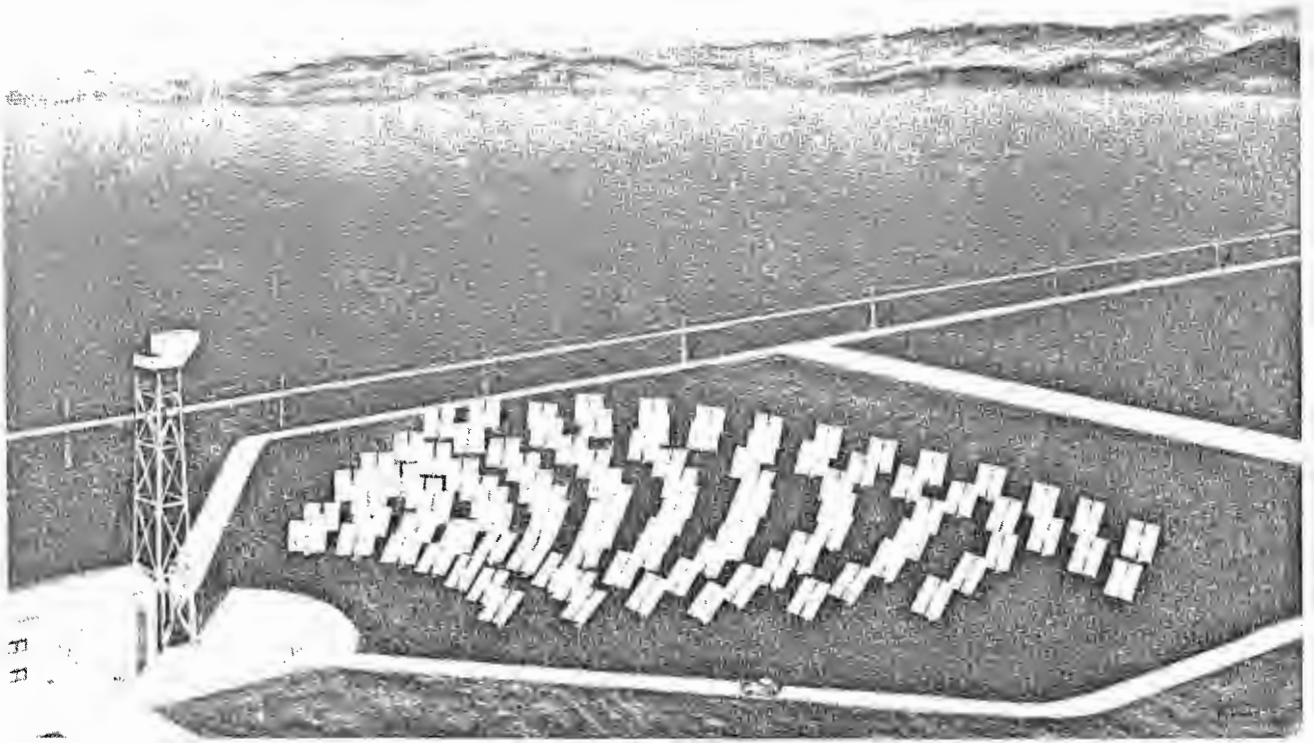
Duration:	1979-1983
Participating Countries:	Austria, Belgium, Germany, Greece, Italy, Spain, Sweden, Switzerland, United States
Operating Agent:	Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt e.V.,LinderHöhe D-5000, Köln 10, Germany
Cost:	1980 - $18 million. Total - $42 million (Minimum contribution 2.5%)

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

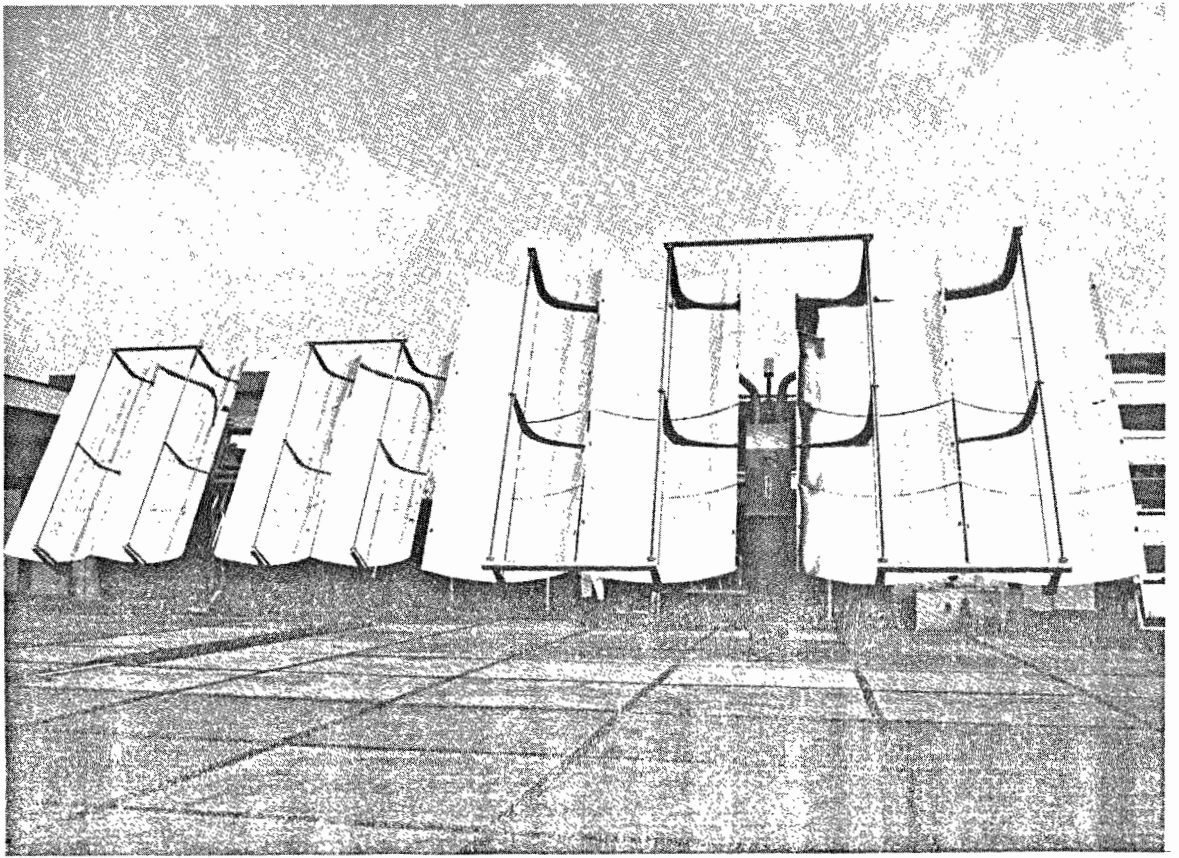


Heliostat with 40 m^2 reflecting surface for the Central Receveir System.

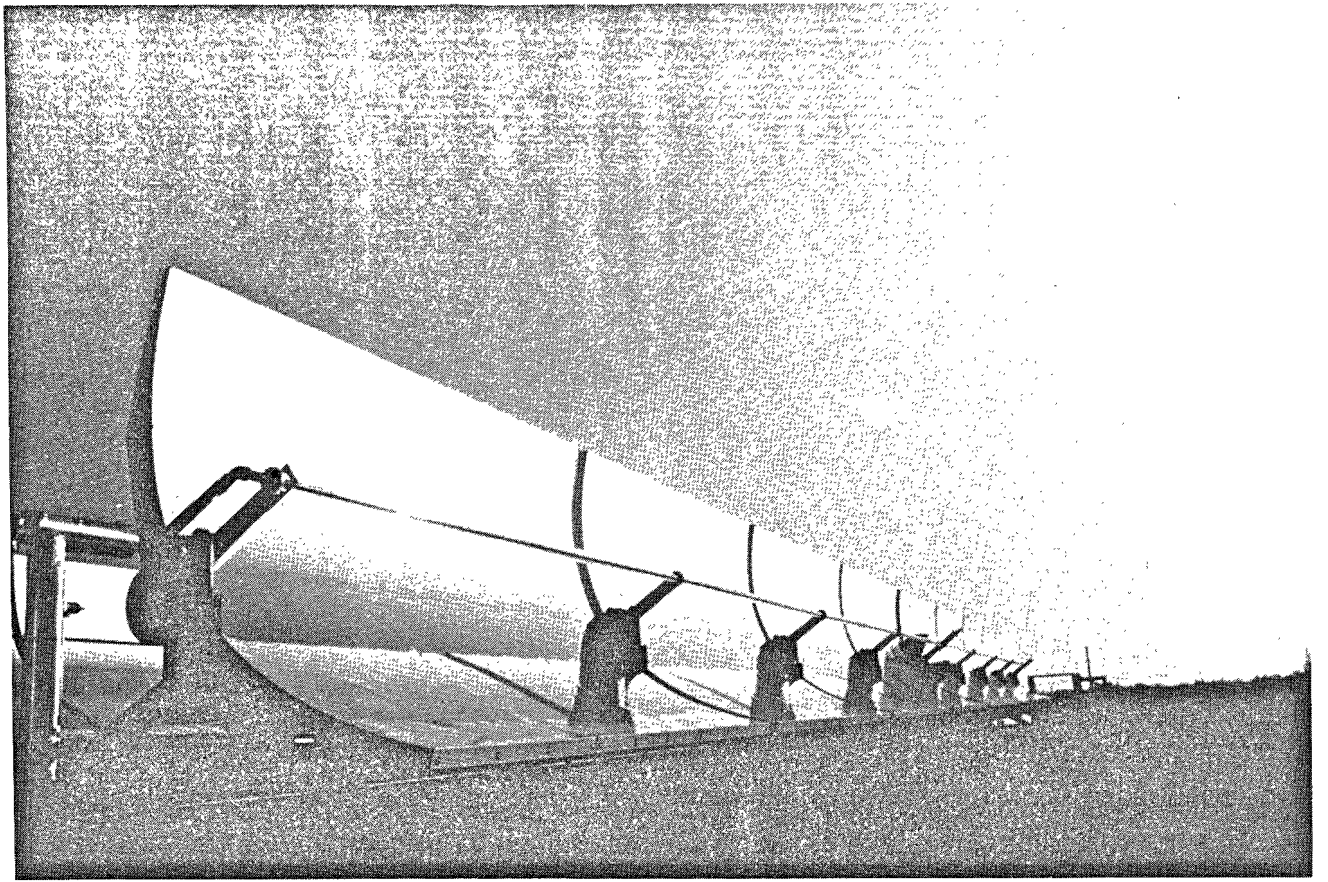
Small Solar Power Systems project: Artist's impression of the Distributed Collector System.



Small Solar Power Systems project: the Central Receiver System.



Parabolic trough collectors for the Distributed Collector System.



Parabolic trough collectors for the Distributed Collector System.

WIND ENERGY

Background

Next to sunlight, wind is the most commonly experienced and universally distributed manifestation of solar energy. It is a relatively untapped source of renewable energy which might, in the long term, make a contribution to meeting world energy demand. Despite the modifications to wind speed and direction caused by heating and cooling of deserts and water, and boundary layer effects due to terrain, the earth's basic wind flow is essentially constant.

Windmills have been in use on a small scale since 2000 BC and are still widespread in some countries, particularly in remote regions. With the advent of suitable materials, there is renewed interest in large scale horizontal and vertical axis wind machines which may become competitive in augmenting of electricity supply.

IEA Activities

The two task-sharing projects are examining wind energy from different perspectives. One through the design, construction and operation of several large horizontal axis installations; the other through joint research and development on the technical, environmental and meteorological aspects of siting and operating wind machines.

Development of Large Scale Wind Energy Demonstrations

The objective and scope of co-operation provided in this agreement were successfully realised during 1980 by an extensive exchange of

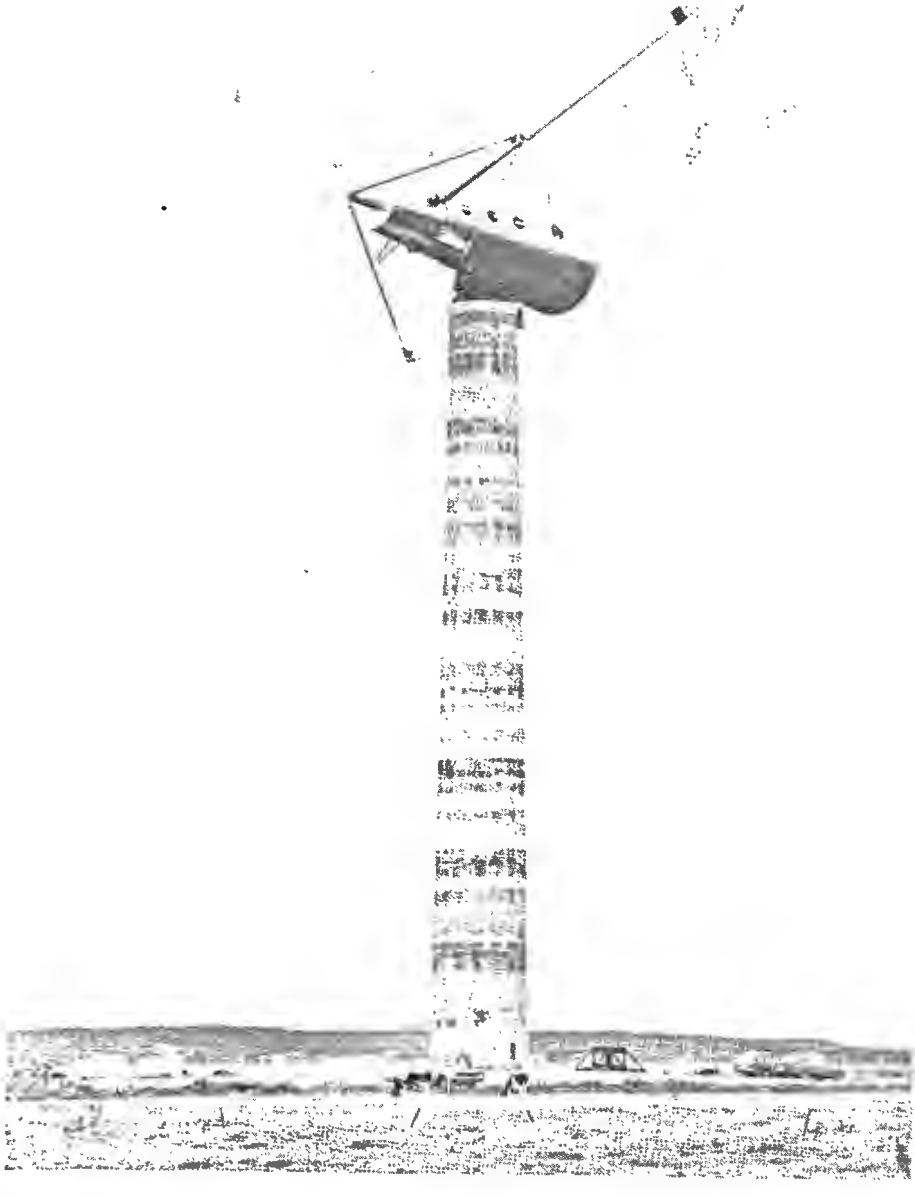
information among the participants and in particular by the progress made in each country's commitment to building and operating large wind machines.

In Denmark, the first of two new 630 KW machines was connected to the electricity grid in September 1979 and the second in August 1980. The electricty production of the first turbine was about 1.5 GWh from May to November 1980, corresponding to a saving of about 300 tonnes of oil.

The aims of the German program are the development and testing of large scale Wind Energy Conversion Systems (WECS) for electricity production while assessing the technical economic and institutional requirements for their widespread use and stimulating their commercial utilization. Following successful completion of the design phase, construction of a 3 MW two-bladed wind system commenced in 1979. When this machine is operational, at its site at the mouth of the river Elbe near the North Sea, its mean annual energy output is expected to be 12 GWh which will be fed into the electricity supply grid. A further 5 MW system is under development, the concept of which will be tested in a 1.6 MW demonstration plant. Preparation for the manufacture of a full size prototype is expected to be complete before the end of 1981.

In Sweden, contracts for the design, manufacture and installation of a 3 MW and a 2 MW prototype were placed during 1979. The first plant is expected to become operational in November 1981. The annual output for each unit will be 6-8 GWh. In the meantime, meteorological information is being gathered from heavily instrumented towers about 140 meters high at the two sites, one on the island of Gotland and the other at Maglarp in southern Sweden.

In 1980 in the United States, four 100 KW (average) experimental WECS were connected to the grid for a total of 15,720 hours, producing 1,553 MWh. The 2 MW turbine operated with good power stability in 1980 but met some problems with noise and television interference. The first of three planned 2.5 MW machines was installed at Goodnoellills in Washington State and first rotation was achieved in November. With one hundred of these units in production, the cost of electricity is estimated to be less than US$0.04/kWh.



Danish 630 kW wind machine.

Duration:	1977-ongoing
Participating Countries:	Denmark, Germany, Sweden, United States
Coordinating Agent:	National Suedish Board of Energy Source Development Box 1103 S-16312 Spanga, Sweden
Cost:	1980 $32 million. (Individually funded projects) Total $202 million

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Research and Development on Wind Energy Conversion Systems (WECS)

The objective of this project is to perform co-operative research, development, demonstration and exchanges of information in the following four tasks:

— Environmental and meteorological aspects of WECS

— Evaluation of models for wind energy siting

— Integration of wind power into national electricity supply systems

— Investigation of rotor stress, operational smoothness of large-scale WECS.

The second is a task-sharing program in which each participant bears its own cost, while the other three are jointly funded. Within the first task, which has the objective of providing information on wind characteristics for the design and operation of large-scale wind energy conversion systems (WECS) and on their environmental effects, a number of studies were completed in 1979.

Results of experiments with models of vertical axis Darrieus type WECS in a wind tunnel have shown that an economically acceptable optimum power output from an array of wind turbines could be reached when they are spaced about 6 diameters apart.

Safety studies which focus on hazards imposed by WECS due to collapse, or to the separation of fractured parts or to pieces of ice acting as missiles, were completed. In another sub-task, engineering models were used to calculate loads and the specification of load cases, the results of which were documented.

A study of the impact of large scale WECS on the performance of electro magnetic wave systems indicates that, without further investigations, limitations regarding siting of WECS can only be given in cases relating to proximity to a radio link, satellite recovery station and broadcasting transmission antenna.

Rotating models or films of prototype WECS in natural environments have been produced to visualise the effects of single and multiple WECS on the landscape. A sub-task on the uncertainty in forecasting wind for the day-to-day operation of WECS found that short-range wind forecasts lack overall quality and accuracy required for the utilisation of wind energy.

The potential savings of co-siting a WECS farm and a short rotation forestry plantation were analysed in 1980. The results show that in this particular case the disadvantages of a biomass production system outweigh the advantages of co-siting, although there may be exceptional sites or circumstances where the two systems could be combined favourably.

The objective of the second task is to evaluate the role of numerical models in the process of selecting sites for wind turbines. Following preparation of a detailed verification plan, three data sets were chosen for the comparison and evaluation of five numerical models. At the completion of the exercise in 1981, recommendations will be made as to the most appropriate model to be used for a number of different meteorological conditions and terrain, and a users manual will be prepared.

The first phase of a study on the integration of wind power into national electricity supply systems has been finished. A report in German, "Windenergie: Eine system-analytische Bewertung des technischen und wirtschaftlichen Potentials für die Stromerzeugung der Bundesrepublik Deutschland" was published in May 1980. A completely revised version of this report has been published under the title "Wind Energy: An Assessment of the Technical and Economic Potential. A Case Study for the Federal Republic of Germany, commissioned by the International Energy Agency". The book presents new technical and economic results for the assessment of wind energy within the electricity supply system of the Federal Republic of Germany (and comparable countries). A computer model was developed, tested and applied in a simulation case of a cluster of windpower plants in the North German coastal region feeding into the entire German electricity grid. At wind power penetrations of 5 to 15 per cent, the fuel savings amounted to between 4.2 and 13.9 per cent of total fuel use without installed wind power generating capacity. In addition it was determined that an increase in the storage capacity of the electricity system as a whole of up to 2 kWh per installed kWh of wind capacity was appropriate, but that the installation of storage systems solely for wind powered generators was not suitable for a national electricity supply system. On the basis of this investigation, the economic wind energy potential of the Federal Republic of Germany is now acknowledged to be comparable to that of hydro power. The methods developed in this study are being used to determine the technical and economic potential of integrating large scale wind powered electricity generating systems into the general power supply systems of Japan, the Netherlands, Sweden and the United States.

The objective of the fourth task was to investigate the possibilities of developing low rotor stressing, high operational smoothness and systems control of a 3 MW WECS. This involves controlling the rotor blades in order to reduce the additional loads resulting from wind shear, gusts, and gravity.

A design for an extremely light but durable 3 MW plant was prepared including a hub which minimises both the stressing of the structure and disturbances of the operational smoothness by external influences. The computational methods used were verified by wind tunnel experiments.

The final report is in preparation. A new study of wake effects behind single turbines and in wind turbine parks was initiated in 1980.

Duration:	1977-1981
Participating Countries:	Austria, Canada, Denmark, Germany, Ireland, Japan, Netherlands, New Zealand, Norway, Sweden, United Kingdom, United States
Operating Agent:	Kernforschungsanlage Jülich GmbH Postfach 1913 D-5170 Jülich, Germany Energionderzoek Centrum Nederland Research Center P.O. Box 1 Petten, Netherlands National Swedish Board for Energy Source Development Box 1103 S-16312 Spanga, Sweden Office of Technical Cooperation United States Department of Energy Washington D.C. 20585
Annual Cost:	$250,000 in equal shares plus up to 2 man years additional effort per Participating Country

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

GEOTHERMAL ENERGY SYSTEMS

Background

Geothermal resources exist everywhere beneath the surface of the earth, although their strength, character and practical usefulness can vary enormously. The presence, in the right location, of water or brine solutions in the pores of rocks can facilitate the exploitation of this resource, yielding hot water or steam. Most of the significant geothermal fields now in operation are dry steam fields feeding into the turbines of power stations. A great majority of existing geothermal fields are, however, hot water fields from which only a small proportion of the energy contained in the field can be extracted. Recent work on geopressured zones containing hot water under extreme pressures has widened the scope for future geothermal operation. The largest potential source of geothermal energy is the thermal energy contained in impermeable rocks of very low porosity. The systems being proposed to extract the energy contained in hot dry rocks are still in the early stages of development. Basically, heat extraction entails the fracturing of the rocks up to 3000 meters below the surface to increase the permeability and the heat transfer surface and then providing a means of transferring the heat to ground level. This is achieved by pumping water into the fractured rock and withdrawing the heated water or steam.

Small-scale transportable geothermal electric generators are needed for testing geothermal resources and for providing electricity at an early stage of the development of large geothermal fields. Such generators must be able to operate under a broad range of geothermal resource conditions (salinity, temperature and pressure). The helical screw expander is one of a number of machines which have been designed to extract the energy from the total flow from a well, rather than from the

water or steam components after they have been separated. An advantage claimed for the helical screw expander is that it not only tolerates substantial deposition of insoluble material but performs more effectively with such deposition. This is of particular interest in the utilisation of high salinity fluids.

IEA Activities

Man-Made Geothermal Energy Systems (MAGES)

The objective of the MAGES project has been to identify possible technical systems for extracting energy from hot dry rocks and delivering it to the surface. A study was undertaken which consisted of a systematic analysis of the components of a MAGES, identification of problems, the search for technically feasible solutions and their economic evaluation.

Following the completion of studies on the components and sub-systems of a large number of MAGES, an economic analysis was performed on selected representative systems.

Completed work on access to a hot dry rock reservoir via boreholes, shafts and caverns demonstrates that despite the special problems encountered in MAGES due to high temperatures, boreholes are the most efficient and economic means. During the study it was found that mined and leached cavities might effectively be used for the storage of geothermal fluid.

In 1979, the mathematical model which had been developed for the examination of heat exchange surfaces was refined and modified. A number of computer runs were performed using input data produced by mathematical simulation of the heat exchange surface. Methods of locating and monitoring heat exchange surfaces have been assessed. The importance of geochemical problems such as corrosion of surface equipment and the dissolution and precipitation of rock under high temperatures and pressures was examined, although laboratory and field data on these processes are scarce.

Results from the examination of heat circulation systems, particularly with respect to changing flow rates due to time and corrosion problems, have been used in assessing the feasibility of proposed MAGES. It was determined that the high cost of installing conventional energy conversion systems underground is not compensated by the insignificant savings in the fluid production system.

The final report of the MAGES project was issued in January 1980. In summary, the results indicate that:

— MAGES are technically feasible and further efforts to develop them are justified;

— Economic feasibility must be demonstrated for each site;

— No major environmental effects are anticipated;

— Main problem areas include the generation of heat exchange surfaces and the geochemical effects of fluid circulation;

— Field tests and more theoretical work are required before optimum MAGES can be designed and operated. To achieve this, extensive laboratory work, mathematical modelling and projects on a pilot scale will be required.

A decision on future work in this area will be taken during 1981.

Duration:	1977-1979
Participating Countries:	Germany, Japan, Sweden, Switzerland, United Kingdom, United States
Operating Agent:	Kernforschungsanlage Jülich GmbH Postfach 1913 D-5170 Jülich, Germany
Cost:	$275,000 (equal shares)

Requests for additional information should be addressed to the

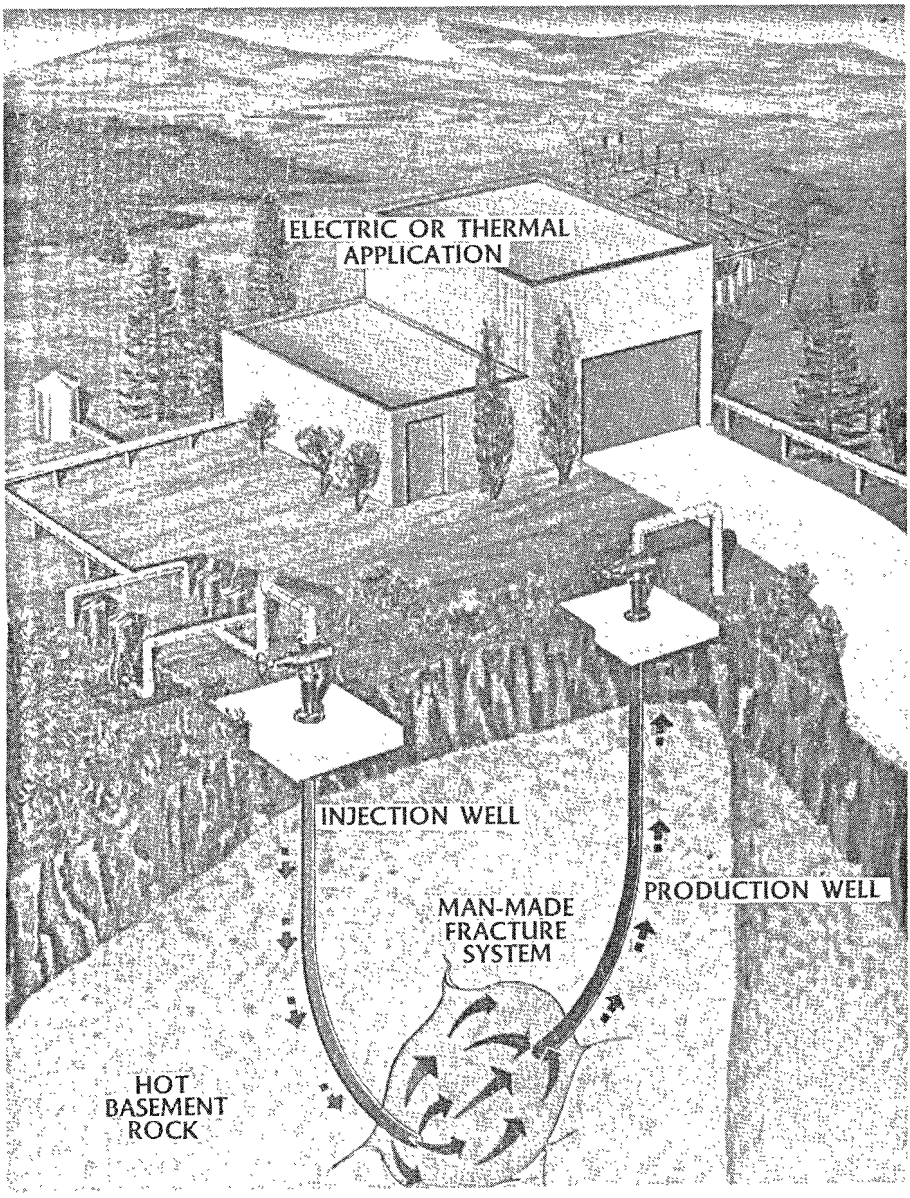
Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.

Hot Dry Rock

Following successful experiments conducted by Los Alamos National Laboratory (LANL) on the extraction of heat from hot dry rocks, a collaborative agreement was concluded in late 1979. The objective of the jointly-funded project is to prove the technical and economic feasibility of hot dry rock as a viable energy resource. Under the project, the LANL will develop and test a large, commercial scale (20-50 MW) loop with a projected life in excess of ten years. Since the start of the joint project, work on the established 5MW thermal reservoir, together with preliminary work on establishing the larger (20-50 MW) reservoir which will be used for the pilot plant, has been carried out. The program during 1980 has included theoretical analysis, data processing and mathematical modelling on the existing system and on geothermal systems in general. Laboratory studies, particularly on rock properties which are an essential precursor to using physical models and chemical studies on rock-water interactions, are in progress. In order to meet commercial requirements for heat extraction from hot dry rocks, Phase 2, a plan to connect two 4,400 metre deep holes through a series of parallel vertical hydraulic fractures, is under construction. The two vertical wells have been completed.

Duration:	1979-1983
Participating Countries:	Germany, Japan, United States
Operating Agent:	Office of Technical Cooperation United States Department of Energy Washington, D.C. 20585
Cost:	1980 $14 million Total $50-60 million

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.



Hot dry rock geothermal energy extraction concept.

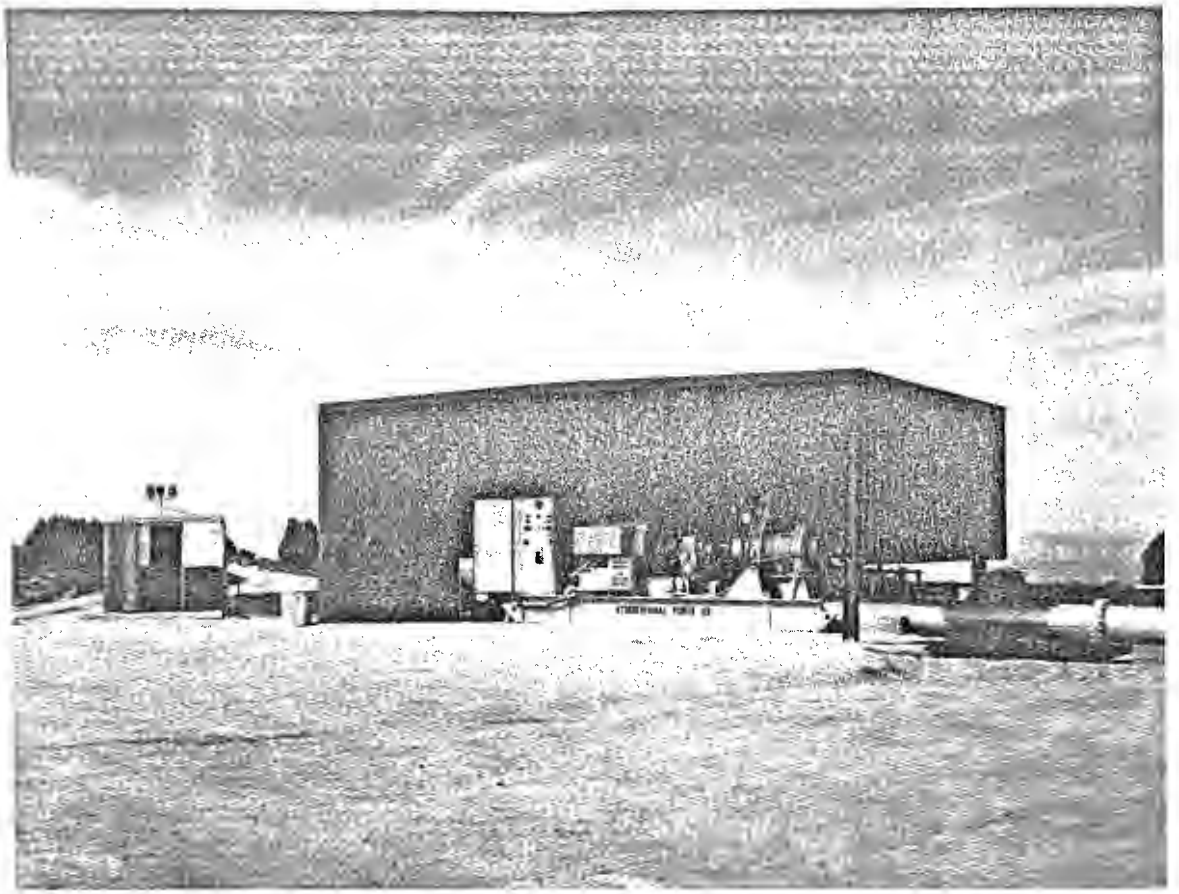
Geothermal Equipment Testing

This task-sharing project, in which Mexico, a non-IEA country is participating, involves the testing of a 1.2 MW helical screw expander and has three objectives: first, to accelerate the development of geothermal resources through the early introduction of advanced geothermal energy conversion technology; secondly, to provide prospective users of geothermal energy with experience in operating geothermal equipment which is technologically advanced; and finally, to develop a data base of the performance and reliability of the power plant for a range of geothermal resource conditions. The data base will be used in assessing benefits and costs involved in the application of the power plant. For this purpose, a comprehensive field test and demonstration program of the helical screw expander is being undertaken in each of the participating countries. Following the completion of a test program in USA, the power plant was moved to Mexico where it was installed and tested during 1980.

During the tests, which are scheduled to last about eight months at each location, the total flow from a geothermal well, either separated and recombined, or without separation, is fed through the expander. Data analysis is carried out by a transportable data acquisition system.

Duration:	1979-1981
Participating Countries:	Italy, Mexico, New Zealand, United States
Operating Agent:	United States Department of Energy
Cost:	1980 $650,000. (Approximately equal shares plus significant US manpower contribution) Total $1.1 million

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.



1.2 MW helical screw expander connected to geothermal source.

OCEAN ENERGY

Background

For many years the prospect of utilising the energy from the sea has been investigated and in some cases it has been harnessed successfully. Advanced studies on tidal power and ambitious projects on ocean thermal energy conversion and wave energy conversion were underway during 1979 as interest in the exploitation of ocean energy in its various forms has continued to increase on a broad front. This truly inexhaustible source of energy has potential applications suitable for a number of different types of location at varying scales of application. For the time being, the IEA has decided to concentrate on augmenting national programs of RD & D aimed at the economical extraction of energy from waves. One of the attractions of this form of energy is that peak periods of wave activity generally correspond to periods of maximum demand for energy.

IEA Activities

Wave Energy Conversion

This jointly funded IEA project has the objective of advancing the state of the art in one of the areas of wave powered electricity generating units. In this particular concept, the action of the waves induces an oscillatory motion in columns of water, which in turn force air through a turbine. This type of device may exist in many configurations and is being examined in a number of countries. For this program, however, a floating ship-like buoy lying in the general direction of the wave motion

is used. The 80m long *Kaimei*, designed by the Japan Marine Science and Technology Center, completed its first open sea-trials during the winter of 1978-1979, in which three Japanese-made generators were used. The *Kaimei* was then returned to harbor to be refitted with a new set of more sophisticated and more efficient generators comprising seven of Japanese and one of United Kingdom design and manufacture, together with a comprehensive data acquisition and telemetry system as specified by participating countries. With the exception of the provision of a generator from the United States, this work was completed on schedule and the buoy underwent sea-trials during the winter of 1979-1980 at its mooring off Yura in the Sea of Japan.

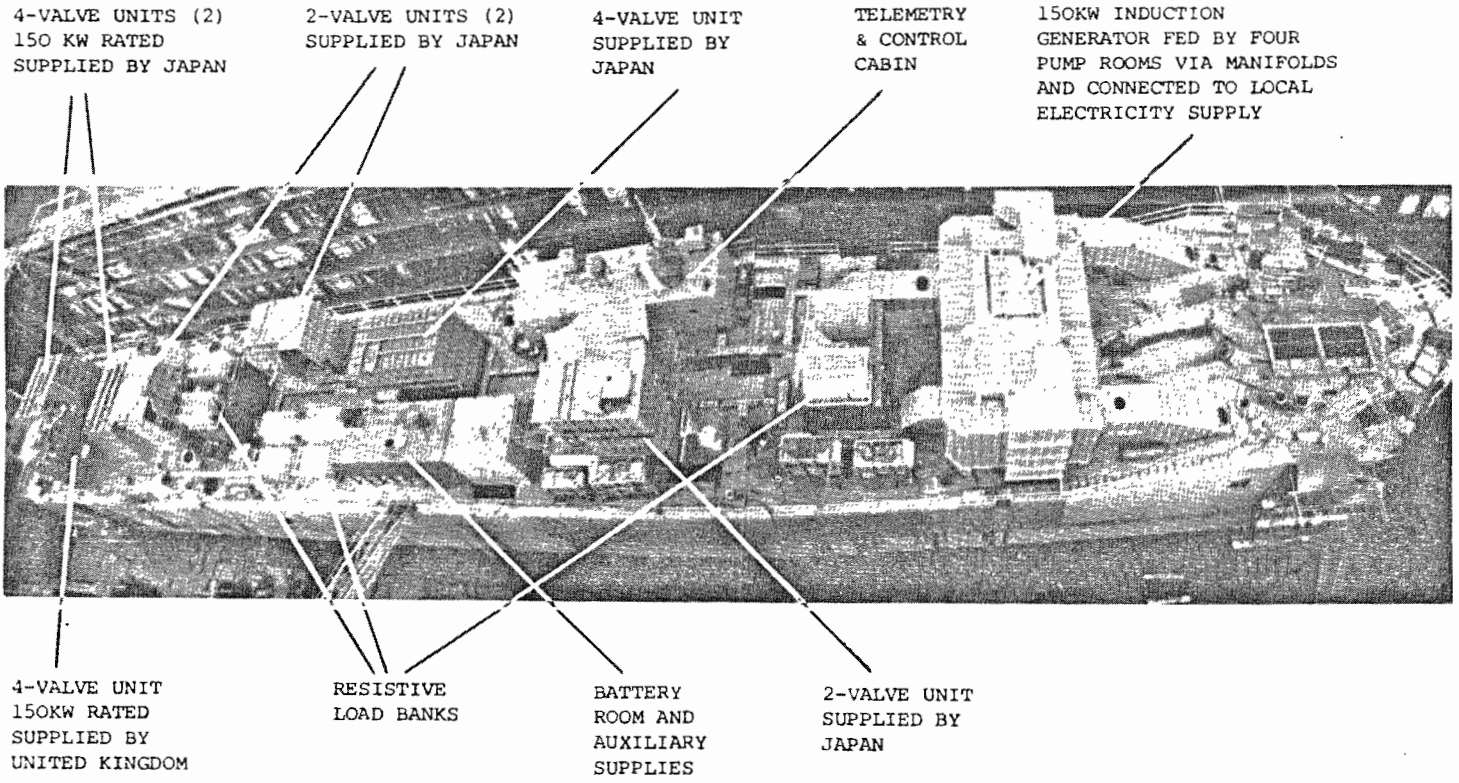
A submarine cable was laid from the test site area to a land fall at Yura during the summer of 1979 and one of the air generators on *Kaimei* provided electricity to the mainland during the winter of 1980, which is a unique achievement for a wave energy system.

Varying conditions were experienced during the sea trials, ranging from an abnormally calm winter sea in 1978-1979, when the maximum power generation on individual turbines was 150 kW, to experiencing two typhoons in late 1979 when minor damage was sustained by all the generators in seas of up to about 10 metres. Results from the sea trial during the winter of 1980 indicated that useful amounts of power can be generated between October and May. The importance of matching vessel size to wave periods for optimum power output was a further result of the 1978-1979 trials. The buoy was designed for six second wave periods and sized accordingly. The most frequent wave periods observed during the single test season were in the seven to nine seconds range and would have better suited a longer vessel.

Following successful completion of the second sea trial in July 1980, the *Kaimei* was removed to harbor and the turbines examined for wear and damage. Data tapes are being analysed prior to preparation of detailed reports of the tests. Initial conclusions show that in addition to generating and transmiting power, a *Kaimei*-like structure can survive the marine winter environment, and that an optimum match of a floating wave power system with the waves it will experience is critical.

Duration:	1978-1980
Participating Countries:	Canada, Ireland, Japan, United Kingdom, United States
Operating Agent:	Japan Marine Science and Technology Center 2-15 Natsuchima-cho, Yokosuka-Shi Kanaguwa Pref., 237, Japan
Cost:	1980 $256,000 Total $2.15 million (minimum contribution 10%)

Requests for additional information should be addressed to the Operating Agent or Director, Energy Research, Development and Technology Application, IEA, Paris.



Plan view of Kaimei during modifications in dry dock at Aioi.

CONVENTIONAL ENERGY RD & D

In addition to the Renewable Energy projects described in the preceding pages, the IEA is conducting a vigorous collaborative program in research, development and demonstration in the technologies related to energy conservation, coal, oil, and nuclear energy.

In the field of conservation, a number of projects are concerned with the design and testing of both individual buildings and whole community systems to optimise energy loads. Other projects are concerned with the development of more efficient heat exchangers, heat pumps, storage systems and multiple cycle generation techniques. In the transportation sector, important joint industrial development work is proceeding on new materials for more efficient automobile engines, while basic collaborative research continues with combustion processes. More recently, the significant potential for energy savings in industry has been reflected in co-operative projects in cement, and pulp and paper manufacturing techniques.

In the general area of fossil fuels, several IEA countries are pooling their knowledge and experience in the development of new techniques and materials for enhancing the recovery of oil from existing wells. However, the main emphasis of the Agency's collaborative program in this area is on coal technology, with a number of "hardware" projects in fluidised bed combustion (both pressurised and atmospheric), and in the use of coal/oil mixtures in utility and industrial boilers. A beginning has also been made in the important aspect of environmental technology with the collaborative project on the development and performance of a low nitrous oxides burner for coal firing. Another project is attempting to develop more efficient coal conversion techniques through an improved understanding of pyrolysis. Jointly funded information services also provide their participating countries

with a continuous fund of material relating to coal reserves and resources, mining and transportation techniques and the many technical and economic aspects of coal utilisation.

The importance of nuclear energy is reflected in the co-operative exchange program (run jointly with the OECD Nuclear Energy Agency) on nuclear reactor safety information, which also includes experience in a number of national safety experimental installations.

Finally, the very substantial long-term energy contribution from thermonuclear fusion is acknowledged in the Agency's co-operative program for the development of superconducting magnets, and materials which will resist disintegration during the reactions which take place in controlled thermonuclear devices.

These IEA activities in non-renewable energy resources cover nearly thirty projects, with a total resource commitment of $250 million equivalent, either in cash or in task-sharing by the nineteen IEA Member countries involved.

A more detailed description of each of the above projects may be found in the Annual Report of the IEA on Energy Research, Development and Demonstration, the 1980-81 edition of which will be available in September 1981, and can be obtained directly from the International Energy Agency, 19, rue de Franqueville, 75775 Paris Cedex 16, France.